FIFTIETH ANNUAL REPORT

OF THE

SECRETARY

OF THE

STATE BOARD OF AGRICULTURE

OF THE

STATE OF MICHIGAN

AND

TWENTY-FOURTH ANNUAL REPORT

OF THE

EXPERIMENT STATION

FROM

JULY 1, 1910, TO JUNE 30, 1911.

BY AUTHORITY

LANSING, MICHIGAN
WYNKOOP HALLENBECK CRAWFORD CO., STATE PRINTERS
1911

REPORT OF THE SECRETARY

OF THE

STATE BOARD OF AGRICULTURE

East Lansing, Mich., *July 1, 1911.*

To Hon. Chase S. Osborn,

Governor of the State of Michigan:

Sir—I have the honor to submit to you herewith, as required by law, the accompanying report for the fiscal year ending June 30, 1911, with supplementary papers.

Very respectfully,

ADDISON M. BROWN,

Secretary of the State Board of Agriculture.

STATE BOARD OF AGRICULTURE.

	Term expires.
ROBERT D. GRAHAM, Grand Rapids.......	1st Monday January, 1914
CHAIRMAN OF THE BOARD.	
WILLIAM L. CARPENTER, Detroit........	1st Monday January, 1912
WILLIAM J. OBERDORFFER, Stephenson..	1st Monday January, 1912
ALFRED J. DOHERTY, Clare	1st Monday January, 1914
WILLIAM H. WALLACE, Saginaw	1st Monday January, 1916
I. ROY WATERBURY, Detroit.............	1st Monday January, 1916
LUTHUR L. WRIGHT, SUPT. OF PUBLIC INSTRUCTION,......	*Ex-Officio.*
JONATHAN L. SNYDER, PRESIDENT OF THE COLLEGE,......	*Ex-Officio.*

ADDISON M. BROWN, East Lansing, Secretary.

BENJAMIN F. DAVIS, Lansing, Treasurer.

STANDING COMMITTEES.

DIVISION OF AGRICULTURE	I. R. Waterbury, R. D. Graham.
DIVISION OF ENGINEERING	A. J. Doherty, W. L. Carpenter.
DIVISION OF HOME ECONOMICS	W. J. Oberdorffer, I. R. Waterbury.
DIVISION OF SCIENCE AND LETTERS..	W. L. Carpenter, W. J. Oberdorffer.
EXPERIMENT STATION	W. H. Wallace, A. J. Doherty.
EMPLOYEES	R. D. Graham, W. L. Carpenter.
FINANCE.........................	R. D. Graham, W. H. Wallace.
FARMERS' INSTITUTES	A. J. Doherty, W. H. Wallace.
BUILDINGS AND COLLEGE PROPERTY..	I. R. Waterbury, W. J. Oberdorffer.

MICHIGAN AGRICULTURAL COLLEGE.

(Under Control of the State Board of Agriculture.)

FACULTY AND OTHER OFFICERS.

JONATHAN L. SNYDER, A. M., Ph. D., LL. D., President; [a b c] Feb. 25, '96.
WM. J. BEAL, Ph. D., D. Sc., Emeritus Professor of Botany; [a b] June 9, '70; [c] June 15, '10.
FRANK S. KEDZIE, M. S., Professor of Chemistry; [a] Sept. 15, '80; [b c] Sept. 1, '02.
LEVI R. TAFT, M. S., Superintendent of Farmers' Institutes and State Inspector of Orchards and Nurseries; [a] Aug. 1, '88; [b c] July 1, '02.
WARREN BABCOCK, B. S., Professor of Mathematics; [a b] June 30, '91; [c] July 1, '09.
WILBUR O. HEDRICK, M. S., Ph. D., Professor of History and Economics; [a b] Aug. 24, '91; [c] June 20, '06.
HERMAN K. VEDDER, C. E., Professor of Civil Engineering; [a b] Sept. 15, '91; [c] July 7, '09.
WALTER B. BARROWS, B. S., Professor of Zoology and Physiology and Curator of the General Museum; [a b c] Feb. 15, '94.
CHARLES E. MARSHALL, Ph. D., Professor of Bacteriology and Hygiene; [a] July 20, '96; [b c] Sept. 1, '02.
RUFUS H. PETTIT, B. S. in Agr., Professor of Entomology; [a] Jan. 1, '97; [b c] Sept. 1, '06.
JOSEPH A. JEFFERY, B. S. A., Professor of Soils and Soil Physics; [a] Sept. 1, '99; [b c] Aug. 6, '08.
MAUDE GILCHRIST, B. S., A. M., Dean of Home Economics; [a b c] Sept. 1, '01.
ADDISON M. BROWN, A. B., Secretary of the College; [a b c] June 1, '02.
ROBERT S. SHAW, B. S. A., Dean of Agriculture; [a b] Sept. 1, '02; [c] Jan. 15, '08.
*CHESTER L. BREWER, B. S., Professor of Physical Culture and Director of Athletics; [a b c] Sept. 1, '03.
ARTHUR R. SAWYER, B. S., E. E., Professor of Physics and Electrical Engineering; [a b c] April 11, '04.
A. CROSBY ANDERSON, B. S., Professor of Dairy Husbandry; [a] Sept. 1, '05; [b] June 10, '09; [c] June 15, '10.
THOMAS C. BLAISDELL, Ph. D., Professor of English Literature and Modern Languages; [a b c] Sept. 1, '06.
GEORGE W. BISSELL, M. E., Dean of Engineering and Professor of Mechanical Engineering; [a b c] June 18, '07.

J. Fred Baker, M. F., Professor of Forestry and Supervisor of Forest Reserve Lands; [a b c] Oct. 1, '07.

Harry J. Eustace, B. S., M. H., Professor of Horticulture; [a b c] Aug. 15, '08.

Victor T. Wilson, M. E., Professor of Drawing and Design; [a b c] Sept. 1, '08.

Walter H. French, M. Pd., Professor of Agricultural Education; [a b c] Sept. 1, '08.

Vernon M. Shoesmith, B. S., Professor of Farm Crops; [a b c] Feb. 14, '09.

Lieut. George M. Holley, M. S., Professor of Military Science and Tactics; [a b c] Sept. 1, '09.

Ernst A. Bessey, Ph. D., Professor of Botany, [a b c] June 15, '10.

Agnes Hunt, B. S., Professor of Domestic Science; [a b c] Sept. 1, '10.

Richard P. Lyman, B. S., M. D. V., Dean of Veterinary Science; Professor of Veterinary Medicine; [a b c] Sept. 28, '10.

John F. Macklin, Professor of Physical Culture; Director of Athletics; [a b c] March 8, '11.

Chace Newman, Assistant Professor of Drawing; [a] Sept. 1, '97; [b c] Sept. 1, '07.

E. Sylvester King, Assistant Professor of English; [a] Jan. 1, '00; [b c] Sept. 1, '02.

Jesse J. Myers, B. S., Assistant Professor of Zoology; [a b] Sept. 1, '01; [c] June 26, '07.

Harry S. Reed, B. S., Assistant Professor of Chemistry; [a b] May 2, '05; [c] Sept. 1, '07.

Joseph A. Polson, B. S., Assistant Professor of Mechanical Engineering; [a b] Sept. 1, '06; [c] May 7, '08.

Anton S. Rosing, B. S. in C. E., Assistant Professor of Civil Engineering; [a b c] Sept. 1, '06.

Arthur J. Clark, A. B., Assistant Professor of Chemistry; [a b] Sept. 1, '06; [c] June 10, '09.

Wylie B. Wendt, B. C. E., Assistant Professor of Civil Engineering; [a b] Sept. 1 ,'06; [c] May 26, '09.

W. Lloyd Lodge, B. S., M. A., Assistant Professor of Physics; [a b] Oct. 1, '06; [c] April 28, '09.

F. Hobart Sanford, B. S., Assistant Professor of Forestry; [a b] Dec. 1, '06; [c] May 1, '09.

Charles P. Halligan, B. S., Assistant Professor of Horticulture; [a b] April 8, '07; [c] May 7, '08.

Otto Rahn, Ph. D., Assistant Professor of Bacteriology; [a] Sept. 1, '07; [b c] Sept. 1, '08.

Richard DeZeeuw, Ph. D., Assistant Professor of Botany; [a b] Sept. 1, '09; [c] Sept. 1, '10.

Edward J. Kunze, B. S., M. E., Assistant Professor of Mechanical Engineering; [a b c] Sept. 1, '10.

Frank W. Chamberlain, B. S., D. V. M., Assistant Professor of Veterinary Science; [a b c] Jan. 1, '11.

The names of instructors whose resignations took effect between June 30 and Sept. 1, '10, do not appear below.

Thomas Gunson, Instructor in Horticulture and Superintendent of the Grounds; [a b] April 1, '91; [c] Sept. 1, '05.

Caroline L. Holt, Instructor in Drawing; [a b c] Sept. 1, '98.

Louise Freyhofer, B. S., Instructor in Music; [a b c] Sept. 1, '02.

Norma L. Gilchrist, A. B., Instructor in English and German; [a b c] Sept. 1, '05.

Bell Farrand, B. S., Instructor in Bacteriology; [a] July 1, '06; [b c] July 1, '09.

L. Zae Northrup, B. S., Instructor in Bacteriology; [a b c] Sept. 1, '07.

Orestes I. Gregg, B. S., Instructor in Horticulture; [a b c] Sept. 1, '07.

Mrs. Minnie A. W. Hendrick, A. B., Instructor in History and Economics; [a] Sept. 1, '07; [b c] Sept. 1, '08.

Wallace B. Liverance, B. S., Instructor in Dairying; [a b c] Sept. 1, '07.

William A. Robinson, A. B., S. T. B., Instructor in English; [a b c] Sept. 1, '07.

Rose M. Taylor, A. B., Instructor in Botany; [a b c] Feb. 8, '08.

Ward Giltner, D. V. M., M. S., Instructor in Veterinary Science; [a b c] July 1, '08.

Herman Hensel, A. B., Instructor in German and English; [a b c] Sept. 1, '08.

Helen I. Michaelides, Instructor in French and English; [a b c] Sept. 1, '08.

Isabel Pearl Snelgrove, Instructor in Drawing; [a b c] Sept. 1, '08.

George A. Brown, B. S., Instructor in Animal Husbandry; [a b c] Sept. 1, '08.

Kate M. Coad, B. S., Instructor in Domestic Art; [a b c] Sept. 1, '08.

Mrs. Lillian L. Peppard, Instructor in Domestic Art and Domestic Science; [a b c] Sept. 1, '08.

William E. Laycock, Instructor in Physics; [a b c] Sept. 1, '08.

*Ward H. Parker, B. S., Instructor in Chemistry; [a b c] Sept. 1, '08.

Antionette A. Robson, Instructor in German and English; [a b c] Jan. 1, '09.

Herbert E. Marsh, B. S., Instructor in Civil Engineering; [a b] Jan. 1, '09; [c] Sept. 1, '10.

Benjamin B. Roseboom, Jr., B. S., Instructor in Zoology; [a b c] Jan. 15, '09.

A. Watt, Instructor in Blacksmithing; [a b c] April 1, '09.

Maurice F. Johnson, B. S., Instructor in Mathematics; [a b c] April 1, '09.

Chas. H. Spurway, B. S., Instructor in Soil Physics; [a b c] Sept. 1, '09.

Harry L. Kempster, B. S., Instructor in Poultry Husbandry; [a b c] Sept. 1, '09.

Harry H. Musselman, B. S., Instructor in Farm Mechanics; [a b c] Sept. 1, '09.

John Bowditch, Jr., Instructor in Animal Husbandry; [a b c] Sept. 1, '09.

George A. Kelsall, B. S., Instructor in Electrical Engineering; [a b c] Sept. 1, '09.

*Max L. Towar, B. S., Instructor in Chemistry; [a b c] Sept. 1, '09.

J. T. Buser, B. S. in C. E., Instructor in Civil Engineering; [a b c] Sept. 1, '09.
Clarence M. Hargrave, A. B., Instructor in Chemistry; [a b c] Sept. 1, '09.
Stanley E. Crowe, B. A., Instructor in Mathematics; [a b c] Sept. 1, '09.
James E. Robertson, B. S., Instructor in Mathematics; [a b c] Sept. 1, '09.
Ernest E. Beighle, B. S., Instructor in Mathematics; [a b c] Sept. 1, '09.
Lloyd C. Emmons, B. S., A. B., Instructor in Mathematics; [a b c] Sept. 1, '09.
Karl E. Hopphan, B. S., Instructor in Mathematics; [a b c] Sept. 1, '09.
Hugh A. Snepp, B. S., Instructor in Mathematics; [a b c] Sept. 1, '09.
*Ernest Roller, B. S., A. M., Instructor in Physics; [a b c] Sept. 1, '09.
Frederick A. Burt, B. S., Instructor in Zoology; [a b c] Sept. 1, '09.
Harold S. Osler, B. S., Instructor in Zoology; [a b c] Sept. 1, '09.
Herman M. Potter, A. B., Instructor in Chemistry; [a b c] Jan. 1, '10.
Richard H. Reece, B. S., Instructor in Mathematics; [a b c] Jan. 1, '10.
Dewey A. Seeley, B. S., Instructor in Meteorology; [a b c] March 16, '10.
Eugenia I. McDaniel, A. B., Instructor in Entomology; [a b c] April 1, '10.
Serg. P. J. Cross, Instructor in Military Science and Tactics; [a b c] May 1, '10.
Frederick A. Gaylord, Instructor in Forestry; [a b c] July 15, '10.
Ruth F. Allen, Ph. D., Instructor in Botany; [a b c] Sept. 1, '10.
Andrew M. Ockerblad, B. S. in C. E., Instructor in Civil Engineering; [a b c] Sept. 1, '10.
Ernest A. Evans, Instructor in Mechanical Engineering; [a b c] Sept. 1, '10.
Max D. Farmer, B. S., Instructor in Drawing; [a b c] Sept. 1, '10.
Ernst G. Fischer, Ph. B., Instructor in German; [a b c] Sept. 1, '10.
Frederick M. Pyke, A. M., Instructor in English; [a b c] Sept. 1, '10.
Grace L. Scott, Instructor in Music; [a b c] Sept. 1, '10.
Don S. Stevens, A. B., Instructor in Economics and Sociology; [a b c] Sept. 1, '10.
Bertram P. Thomas, B. A., Instructor in Drawing; [a b c] Sept. 1, '10.
Bertha E. Thompson, A. B., Instructor in Botany; [a b c] Sept. 1, '10.
George H. VonTungeln, A. M., Instructor in English; [a b c] Sept. 1, '10.
Florence Chapman, Instructor in Physical Culture; [a b c] Sept. 1, '10.
Grace E. Stevens, A. B., Instructor in Domestic Science; [a b c] Sept. 1, '10.
Raymond D. Penney, Instructor in English; [a b c] Sept. 1, '10.
Louis B. Mayne, A. B., Instructor in English; [a b c] Sept. 1, '10.
James A. Morse, Instructor in Mechanical Engineering; [a b c] Sept. 1, '10.
Arthur Smith, Instructor in Mechanical Engineering; [a b c] Sept. 1, '10.
Fred Killeen, Director of M. A. C. Chorus; [a b c] Sept. 1, '10.
Oren L. Snow, B. S., Instructor in Physics; [a b c] Sept. 1, '10.
William H. Brown, Ph. D., Instructor in Plant Physiology; [a b c] Nov. 12, '10.
George H. Coons, A. M., Instructor in Plant Pathology; [a b c] Jan. 1, '11.
*James E Gillespie, M. A., Instructor in History; [a b c] Jan. 1, '11.
Oscar B. Park, Ph. B., Instructor in Zoology; [a b c] Jan. 1, '11.
Irving Gilson, B. S., Instructor in Forestry; [a b c] Jan. 1, '11.
*R. L. Nye, Instructor in Mathematics; [a b c] Feb. 1, '11.

Floyd E. Fogle, Instructor in Farm Mechanics; [a b c] March 8, '11.
Charles H. McLean, Instructor in History and Economics; [a b c] April 1, '11.
Warren S. Robbins, Instructor in Bacteriology; [a b c] April 1, '11.
Grover J. Secord, Instructor in Chemistry; [a b c] April 1, '11.
Burt K. Philp, Instructor in Civil Engineering; [a b c] April 1, '11.
James E. Shaw, B. S., Instructor in Civil Engineering; [a b c] April 1, '11.
Linda E. Landon, Librarian; [a b c] Aug. 24, '91.
E. C. Baker, Foreman of Foundry; [a b c] Nov. 1, '97.
Lory F. Newell, Engineer; [a b c] Jan. 1, '98.
Benjamin A. Faunce, Clerk to President and Editor M. A. C. Record; [a] Sept. 1, '99; [b c] April 1, '10.
Rowena Ketchum, Nurse in charge of College Hospital; [a b c] Sept. 1, '00.
Edwyn A. Bowd, College Architect; [a b c] Jan. 1, '02.
Andrew P. Krentel, Foreman of Wood Shop; [a b c] Sept. 1, '02.
Elida Yakeley, Registrar; [a] July 15, '03; [b c] June 1, '08.
Charles W. Brown, B. S., Assistant in Bacteriology; [a b c] Aug. 1, '06.
William R. Holmes, Foreman of Forge Shop; [a b c] Sept. 1, '06.
Jacob Schepers, Cashier; [a b] May 1, '07; [c] July 1, '07.
Luther F. Jenison, Bookkeeper; [a b c] May 1, '07.
*Agnes E. Crumb, Assistant Librarian; [a] Aug. 12, '07; [b c] March 1, '08.
Ralph S. Hudson, B. S., Farm Foreman; [a b c] Dec. 1, '07.
Maud A. Meech, Chief Clerk to Secretary, [a b] April 1, '08; [c] Sept. 1, '10.
John H. Rand, Purchasing Agent; [a b c] Aug. 1, '08.
Albert H. Davis, Foreman of the Horticultural Department; [a b c] Sept. 1, '08.
W. F. Raven, Live stock Field Agent; [a b c] April 1, '09.
O. K. White, B. S., Horticultural Field Agent; [a b c] April 1, '09.
E. C. Crawford, Shop Engineer; [a b c] July 1, '09.
Katherine M. Cameron, House Director; [a b c] Sept. 1, '09.
A. R. Pott, Field Agent Soils and Crops; [a b c] Sept. 9, '09.
*Mrs. C. M. Dudd, Clerk to President; [a b c] Jan. 1, '10.
Louise E. Walsworth, Clerk to Secretary; [a b c] Jan. 17, '10.
Mabel Nixon, Clerk to President; [a] March 1, '10; [b c] March 13, '11.
John A. Neal, Assistant in Machine Shop; [a b c] Nov. 14, '10.

EXPERIMENT STATION WORKERS.

Frank A. Spragg, M. S., Assistant in Crops, (Plant Breeding); [a b c] Dec. 1, '06.
Lulu M. Smith, B. S., Assistant in Bacteriology; [a b c] April 1, '08.
Charles S. Robinson, M. S., Research Assistant in Chemistry; [a b c] Sept. 1, '09.
Myra V Bogue, Bulletin Clerk; [a b c] Jan. 1, '10.
Orrin B. Winter, B. S., Assistant in Chemistry; [a b c] Feb. 15, '10.
W. Allerton Wentworth, B. S., Research Assistant in Bacteriology; [a b c] May 2, '10.

*Resigned.
a First appointment.
b Present appointment.
c Present title.

AGRICULTURAL EXPERIMENT STATION

OF THE

MICHIGAN AGRICULTURAL COLLEGE

(Under the control of the State Board of Agriculture.)

STATION COUNCIL.

JONATHAN L. SNYDER, A. M., Ph. D., L. L. D. — President, *Ex-officio*.
ROBERT S. SHAW, B. S. A., — Director.
CHARLES E. MARSHALL, Ph. D., — Scientific and Vice-Director and Bacteriologist.
HARRY J. EUSTACE, B. S., — Horticulturist.
J. FRED BAKER, M. F., - Forester.
A. CROSBY ANDERSON, B. S., — Dairy Husbandman.
RUFUS H. PETTIT, B. S. A., — Entomologist.
ANDREW J. PATTEN, B. S., — Chemist.
JOSEPH A. JEFFERY, B. S. A., — Soil Physicist.
ERNST A. BESSEY, Ph. D., — Botanist.
VERNON M. SHOESMITH, B. S., — Farm Crops Experimenter.
ADDISON M. BROWN - - Secretary.

ADVISORY AND ASSISTANT STAFF.

CHARLES P. HALLIGAN, B. S., — Asst. Horticulturist.
OTTO RAHN, Ph. D., — Asst. Bacteriologist.
GEORGE A. BROWN, B. S., — Asst. Animal Husbandman.
GEORGE D. SHAFER, Ph. D., — Asst. Entomologist.
WARD GILTNER, D. V. M. M. S., — Research Asst. in Bacteriology.
CHARLES W. BROWN, B. S., — Research Asst. in Bacteriology.
W. S. ROBBINS, B. S., — Asst. in Bacteriology.
WM. H. BROWN, Ph. D., — Research Asst. in Plant Physiology.
GEO. H. COONS, A. B., A. M., — Research Asst. in Plant Pathology.
FRANK A. SPRAGG, M. S., — Asst. in Crops (Plant Breeding.)
L. ZAE NORTHRUP, B. S., — Asst. in Bacteriology.
LULU M. SMITH, B. S., — Asst. in Bacteriology.
LINDA E. LANDON, - - Librarian.
CHARLES S. ROBINSON, M. S., — Research Asst. in Chemistry.
W. ALLERTON WENTWORTH, B. S., — Research Asst. in Bacteriology.
ORRIN B. WINTER, B. S., — Asst. in Chemistry.
EUGENIA I. MCDANIEL. — Asst. in Entomology.
GEO. BOUYOUCOS, Ph. D., — Research Asst. in Soil Physics.
MYRA V. BOGUE - Bulletin Clerk.

STANDING COMMITTEE IN CHARGE.

HON. WILLIAM H. WALLACE - - - - - - - - - - - Saginaw.
HON. ALFRED J. DOHERTY - - - - - - - - - - - - - Clare.

STATE WEATHER SERVICE.

(Under the control of the State Board of Agriculture.)

OFFICERS OF THE SERVICE.

Director - - - - - - - C. F. SCHNEIDER, U. S. Weather Service.

ACCOUNTS OF

THE MICHIGAN AGRICULTURAL COLLEGE

FOR THE YEAR ENDING JUNE 30, 1911.

SECRETARY'S FINANCIAL REPORT.

			Dr.	Cr.
July 1, 1910.	To cash on deposit, College Treasurer		$14,665 15	
July 1, 1910.	To cash on hand		2,748 87	
June 30, 1911.	To special appropriation receipts		52,825 49	
	From State Treasurer	$16,000 00		
	From United States Treasurer	30,000 00		
	From institution and other sources	6,825 49		
June 30, 1911.	By special appropriation disbursements			$54,615 00
June 30, 1911.	To current account receipts		375,172 12	
	From State Treasurer, land grant interest	$70,304 15		
	From State Treasurer, one-tenth mill tax.	163,410 00		
	From U. S. Treasurer, Morrill Fund	45,000 00		
	From institution and other sources	95,270 10		
	From South Haven Experiment Station	298 39		
	From U. P. Experiment Station	889 48		
	By general account disbursements			$376,575 82
	From current account	$353,777 71		
	From supplementary accounts	22,798 11		
June 30, 1911.	By cash on hand			3,498 72
June 30, 1911.	By cash on deposit			10,722 09
			$445,411 63	$445,411 63

TABLE NO. 1.—*Tabular exhibit of Secretary's report.*

	Balance sheet July 1, 1910.		Transactions July 1, 1910, to June 30, 1911.		Balance sheet June 30, 1911.	
	Dr.	Cr.	Dr.	Cr.	Dr.	Cr.
Cash	$2,748 87			$749 85	$3,498 72	
College Treasurer*	14,665 15		$3,943 06		10,722 09	
Special appropriations		$12,072 85	52,825 49	54,615 00		
Current accounts		5,341 17	373,983 47	353,777 71		$3,937 47
Supplementary accounts			1,188 65	22,798 11		10,283 34
Totals	$17,414 02	$17,414 02	$431,940 67	$431,940 67	$14,220 81	$14,220 81

*Treasurer's statement is greater July 1, 1910 by $5,951.23 and June 30, 1911, by $7,548.96; warrants outstanding and an amount of $12.50 not received by treasurer.

TREASURER'S ACCOUNT.

	Dr.	Cr.
Balance on July 1, 1910	$20,616 38	
Receipts from State Treasurer and Secretary of College	426,420 38	
Interest on deposits during year	814 88	
Warrants paid July 1, 1910 to June 30, 1911		$429,580 59
Balance on hand June 30, 1911		18,271 05
Total	$447,851 64	$447,851 64

TABLE NO. 2.—*Statement of special appropriation accounts for fiscal year ending June 30, 1911.*

Name of appropriation.	Balance of accounts, July 1, 1910.		Receipts during fiscal year.		Total available.	Total expended.	Balance of account, June 30, 1911.	
	Dr.	Cr.	From State Treasurer.	From institution and other sources.			Dr.	Cr.
Experiment Station		$2,552 12	*$30,000 00	$4,786 23	$37,338 35	$36,075 66		$1,262 69
Nursery License and Inspection				1,187 95	1,187 95	1,187 95		
Sundry Improvements		1,877 27	5,000 00	813 81	7,691 08	5,272 46		2,418 62
Semi-Centennial		147 55			147 55	147 55		
Agricultural Building		1,105 45			1,105 45	1,105 45		
Addition to Botanical Building		6,376 45			6,376 45	6,376 45		
Sayer Fund		12 50		37 50	50 00			50 00
Addition to Chemical Laboratory			10,000 00		10,000 00	3,431 41		6,568 59
Weather Bureau		1 51	1,000 00		1,001 51	1,018 07	$16 56	
Total		$12,072 85	$46,000 00	$6,825 49	$64,898 34	$54,615 00	$16 56	$10,299 90

*United States Treasurer.

TABLE NO. 3.—*William Smith Sayer, scholarship fund.*

Fund.	Year ending June 30.	Income.	Income expended to	Amount.	Balance including principal.
$500.00 received of F. F. Sayer, administrator of the estate of William Smith Sayer, to establish Scholarship in Bacteriology.......	1910	$32 25	A. McVittie.	$19 75	$512 50
	1911	37 50	....	....	550 00
		$69 75		$19 75	

TABLE NO. 4.—*Current account, July 1, 1910, to June 30, 1911.*

On account of—	Dr. To disbursements.	Cr. By receipts.
U. S. Treasurer, 21st annual payment under act of Congress of August 1890..........	....	$45,000 00
State Treasurer, one-tenth mill fund..........	....	163,410 00
State Treasurer, interest on proceeds of sales of U. S. land grant..........	....	70,304 15
Advertising..........	$2,638 47	192 95
Agricultural education..........	919 80	....
Animal husbandry..........	7,938 33	4,682 92
Athletics..........	1,412 25	1,335 27
Bacteriological..........	8,100 96	8,105 52
Botanical..........	3,429 09	85 61
Chemical..........	8,462 89	3,890 61
Civil engineering..........	2,510 95	695 00
Cleaning..........	3,655 42	567 58
College extension..........	2,223 29	14 38
Contingent building..........	26,648 11	34,467 89
Crops..........	840 87	24 52
Dairy husbandry..........	16,863 89	13,809 81
Dean's office..........	1,749 00	79 72
Drawing..........	465 74	20 50
Electric lighting..........	6,784 34	3,299 40
English..........	562 71	52 00
Entomology..........	1,224 32	82 60
Farm & horses..........	6,967 09	4,419 68
Farm mechanics..........	1,895 77	934 62
Forestry..........	6,819 94	1,692 54
Heating..........	28,188 78	1,058 88
History..........	399 55	35 00
Horticultural..........	7,643 26	845 68
Home economics..........	3,095 67	1,376 23
Library..........	5,187 11	31 44
Mathematical..........	184 40	137 00
Mechanical..........	12,036 54	1,825 68
M. A. C. Record..........	1,491 03	449 05
Meteorology..........	86 54	83 00
Military..........	1,031 22	16 00
Miscellaneous..........	6,793 50	3,501 45
Office, secretary's..........	1,119 51	43 50
Office, president's..........	1,873 52	579 83
Physical..........	3,374 97	787 84
Poultry..........	2,750 48	1,555 20
Registrar..........	684 12	....
Salaries..........	157,027 47	1,737 20
Soils..........	826 62	3 62
Special courses..........	3,501 42	1,707 91
Telephones..........	1,193 88	614 70
Veterinary..........	1,455 59	31 94
Zoological..........	1,718 70	395 05
Total..........	$353,777 71	$373,983 47
Supplementary accounts:		
Bulletins..........	4,183 76	....
Farmers' institutes..........	8,842 65	78
South Haven experimental station..........	1,976 91	298 39
Upper Peninsula experiment station..........	7,794 79	889 48
Balance beginning of period July 1, 1910..........	....	5,341 17
Balance beginning of period July 1, 1911..........	3,937 47	....
Total..........	$380,513 29	$380,513 29

TABLE NO. 5.—*Experiment Station accounts for fiscal year ending June 30, 1911.*

On account of—	Disbursements.			Dr. Total disbursements for each dep't.	Cr. By receipts.
	Adams.	Hatch.	State.		
Balance, July 1, 1910	....	....	....	....	$2,552 12
U. S. Treasurer for fiscal year	....	....	....	....	30,000 00
Fertilizer fees	....	....	$20 00	$20 00	4,540 00
Bacteriological department	$2,199 48	$558 53	745 46	3,503 47	....
Botanical department	2,332 15	237 08	256 93	2,826 16	....
Chemical department	997 52	1,038 59	1,617 63	3,653 74	26 18
Director's office	....	314 29	767 78	1,082 07	1 51
Entomological department	321 86	564 40	66 56	952 82	06
Farm department	....	2,034 89	27 69	2,062 58	210 98
Horticultural department	....	1,215 40	....	1,215 40	....
Library	....	798 57	80 55	879 12	7 50
Salaries	8,851 80	8,238 25	2,278 60	19,368 65	....
Office, secretary's	....	....	15 00	15 00	....
Soil physicist	297 19	....	199 46	496 65	....
Balance, June 30, 1911	....	....	....	1,262 69	....
Total	$15,000 00	$15,000 00	$6,075 66	$37,338 35	$37,338 35

TABLE NO. 6.—*Positions and salaries as shown by pay roll dated June 30, 1911.*

Grade.	Rate per year.	Classification. Current.	Classification. Experiment station.	Other sources.	
Administration and Miscellaneous					
President's office:					
President	$5,000 00	$5,000 00	....	....	House.
Editor, M. A. C. Record	1,100 00	1,100 00	....	....	....
Clerk	600 00	600 00	....	....	....
Secretary's office:					
Secretary	2,250 00	550 00	$700 00	$1,000 00	House.
Cashier	1,400 00	1,200 00	200 00	....	....
Bookkeeper	750 00	650 00	100 00	....	....
Chief clerk	900 00	775 00	125 00	....	....
Clerk	500 00	500 00	....	....	....
Purchasing agent	1,100 00	1,100 00	....	....	....
Registrar's office:					
Registrar	1,000 00	1,000 00	....	....	....
Institute and Nursery Inspector:					
Superintendent	2,000 00	2,000 00	....	....	House.
Library:					
Librarian	1,000 00	880 00	120 00	....	Rooms.
Asst. Librarian	650 00	650 00	....	....	....
Miscellaneous:					
Architect	1,500 00	1,500 00	....	....	....
Engineer	1,200 00	1,200 00	....	....	....
Plumber	900 00	900 00	....	....	....
Night Watchman	600 00	600 00	....	....	....
Nurse	450 00	450 00	....	....	....
Stenographer	540 00	540 00	....	....	....
Stenographer	530 00	530 00	....	....	....
Stenographer	480 00	480 00	....	....	....
Stenographer	480 00	480 00	....	....	....
Stenographer	540 00	270 00	270 00	....	....
Instructor Meteorology	300 00	300 00	....	....	....
Instructor Music	240 00	240 00	....	....	....
Division of Home Economics					
Dean	1,700 00	1,700 00	....	....	Rooms.
Dept. Domestic Art:					
Instructor	800 00	800 00	....	....	Rooms.
Instructor	750 00	750 00	....	....	Rooms.
Dept. Domestic Science:					
Professor	1,300 00	1,300 00	....	....	Rooms.
Instructor	500 00	500 00	....	....	Rooms.
Instructor Music	1,000 00	1,000 00	....	....	....
Asst. Instructor Music	500 00	500 00	....	....	Rooms.
Instructor Physical Culture	500 00	500 00	....	....	Rooms.
House Director	550 00	550 00	....	....	Rooms.
Division of Engineering					
Dean	3,000 00	3,000 00	....	....	House.
Clerk	600 00	600 00	....	....	....
Dept. of Civil Engineering:					
Professor	2,500 00	2,500 00	....	....	House.
Asst. Professor	1,400 00	1,400 00	....	....	....
Asst. Professor	1,400 00	1,400 00	....	....	....
Instructor	800 00	800 00	....	....	....
Instructor	800 00	800 00	....	....	....
Instructor	900 00	900 00	....	....	....
Instructor	960 00	960 00	....	....	....
Instructor	960 00	960 00	....	....	....
Dept. of Drawing and design:					
Professor	2,300 00	2,300 00	....	....	....
Ast. Professor	1,400 00	1,400 00	....	....	....
Instructor	850 00	850 00	....	....	....
Instructor	700 00	700 00	....	....	....
Instructor	750 00	750 00	....	....	....
Instructor	750 00	750 00	....	....	....

TABLE NO. 6.—*Continued.*

Grade.	Rate per year.	Classification. Current.	Classification. Experiment station.	Other sources.	
Dept. of Mechanical Engineering:					
Asst. Professor	$1,800 00	$1,800 00			
Asst. Professor	1,400 00	1,400 00			
Instructor	660 00	660 00			
Instructor	720 00	720 00			
Instructor	900 00	900 00			
Instructor	1,200 00	1,200 00			
Foreman Wood Shop	900 00	900 00			
Foreman Foundry	900 00	900 00			
Foreman Forge Shop	900 00	900 00			
Shop Engineer	780 00	780 00			
Dept. of Physical and Elect. Eng:					
Professor	2,300 00	2,300 00			
Asst. Professor	1,400 00	1,400 00			
Instructor	1,000 00	1,000 00			
Instructor	1,000 00	1,000 00			
Instructor	1,200 00	1,200 00			
Instructor	750 00	750 00			
Division of Science and Letters					
Dept. of Bacteriology:					
Professor	3,000 00	2,000 00	$1,000 00		
Asst. Professor	1,600 00	1,350 00	250 00		
Research Asst. in Bacteriology	1,500 00	750 00	750 00		
Research Asst. in Bacteriology	1,200 00	250 00	950 00		
Asst. in Bacteriology	750 00	500 00	250 00		
Asst. in Bacteriology	500 00		500 00		
Asst. in Bacteriology	1,000 00		1,000 00		
Asst. in Bacteriology	1,200 00	600 00	600 00		
Instructor in Bacteriology	700 00	700 00			
Department of Botany:					
Professor	2,000 00	1,800 00	200 00		House.
Asst. Professor	1,200 00	1,200 00			
Asst. in Botany	1,200 00	300 00	900 00		
Asst. in Botany	1,200 00	300 00	900 00		
Instructor	900 00	900 00			
Instructor	750 00	750 00			
Instructor	750 00	750 00			
Department of Chemistry:					
Professor	3,000 00	3,000 00			
Asst. Professor	1,500 00	1,500 00			
Asst. Professor	1,350 00	1,350 00			
Instructor	850 00	850 00			
Instructor	900 00	900 00			
Instructor	850 00	850 00			
Department of English:					
Professor	2,000 00	2,000 00			House.
Asst. Professor	1,400 00	1,400 00			
Instructor	750 00	750 00			
Instructor	800 00	800 00			
Instructor	900 00	900 00			
Instructor	750 00	750 00			
Instructor	800 00	800 00			
Instructor	800 00	800 00			
Instructor	750 00	750 00			
Instructor	800 00	800 00			
Instructor	1,000 00	1,000 00			
Instructor	900 00	900 00			
Department of Entomology:					
Professor	2,000 00	1,200 00	800 00		House.
Instructor	800 00	450 00	350 00		
Research Asst. in Entomology	1,500 00		1,500 00		
Department of History:					
Professor	2,300 00	2,300 00			
Associate Professor	1,600 00	1,600 00			
Instructor	800 00	800 00			
Instructor	800 00	800 00			
Instructor	1,000 00	1,000 00			

TABLE NO. 6.—*Continued.*

Grade.	Rate per year.	Classification. Current.	Classification. Experiment station.	Other sources.	
Department of Military Science:					
Sergeant	$500 00	$500 00			
Department of Mathematics:					
Professor	2,300 00	2,300 00			
Instructor	800 00	800 00			
Instructor	900 00	900 00			
Instructor	900 00	900 00			
Instructor	1,000 00	1,000 00			
Instructor	1,000 00	1,000 00			
Instructor	800 00	800 00			
Instructor	900 00	900 00			
Instructor	800 00	800 00			
Department of Physical Culture:					
Professor	2,400 00	2,400 00			
Department of Zoology:					
Professor	2,000 00	2,000 00			House.
Asst. Professor	1,400 00	1,400 00			
Instructor	800 00	800 00			
Instructor	800 00	800 00			
Instructor	900 00	900 00			
Instructor	720 00	720 00			
Division of Veterinary Science					
Professor	2,500 00	2,500 00			
Asst. Professor	1,600 00	1,600 00			
Division of Agriculture					
Dean	3,000 00	2,000 00	$1,000 00		House.
Clerk	1,000 00	500 00	500 00		
Department of Animal Husdandry:					
Instructor	1,200 00	1,000 00	200 00		
Instructor	700 00	700 00			
Department of Dairy Husbandry:					
Professor	1,900 00	1,700 00	200 00		
Instructor	1,200 00	1,200 00			
Clerk	480 00	480 00			
Department of Poultry:					
Instructor	1,200 00	1,200 00			
Department of Farm Crops:					
Professor	2,200 00	2,000 00	200 00		
Asst. to Farm Crops	1,200 00		1,200 00		
Department of Soils:					
Professor	2,300 00	2,100 00	200 00		
Instructor	1,000 00	1,000 00			
Research Asst. in Soils	1,200 00		1,200 00		
Department of Farm Mechanics:					
Instructor	1,200 00	1,200 00			
Instructor	750 00	750 00			
Instructor	720 00	720 00			
Department of College Extension:					
Field Agent Live Stock	1,500 00	1,500 00			
Field Agent Farm Crops	780 00	780 00			
Field Agent Horticulture	1,350 00	1,350 00			
Department of Farm & Horses:					
Foreman College Farm	800 00	800 00			House.
Dept. of Agricultural Education:					
Professor	2,300 00	2,300 00			
Department of Forestry:					
Professor	2,300 00	2,100 00	200 00		
Asst. Professor	1,600 00	1,600 00			
Instructor	1,400 00	1,400 00			

TABLE NO. 6.—*Concluded.*

Grade.	Rate per year.	Classification.		Other sources.	
		Current.	Experiment Station.		
Department of Horticulture:					
Professor	$2,000 00	$1,800 00	$200 00	....	House.
Asst. Professor	1,600 00	1,400 00	200 00	....	....
Instructor	1,200 00	1,200 00	....	....	....
Instructor	1,200 00	1,200 00	....	....	House.
Foreman of Grounds	600 00	600 00	....	....	House.
Chemistry Dept. Experiment Sta.:					
Chemist	2,000 00	....	2,000 00	....	....
Research Asst. in Chemistry	1,200 00	....	1,200 00	....	....
Asst. in Chemistry	900 00	....	900 00	....	....
Bulletin Clerk	480 00	....	480 00	....	....
Total	$189,320 00	$166,975 00	$21,345 00	$1,000 00	....

TABLE NO. 7.—*Income of the Michigan Agricultural College from all outside sources from the date of its foundation to the present time.*

Year.	From State Legislature.			From U. S. Congress.			Total.
	For current expenses.	For special purposes.	Land sales, salt spring and swamp land grants.	Morrill act of 1862, interest from land grant and trespass.	Hatch act of 1887, and Adams act of 1906, experiment station.	Morrill act of 1890, supplementary endowment.	
1855			$56,320 00				$56,320 00
1856							
1857	$40,000 00						40,000 00
1858							
1859	37,500 00						37,500 00
1860							
1861	6,500 00		152 25				6,652 25
1862	10,000 00		218 97				10,218 97
1863	9,000 00		407 80				9,407 80
1864	9,000 00		726 09				9,726 09
1865	15,000 00		1,156 61				16,156 61
1866	15,000 00		1,094 27				16,094 27
1867	20,000 00		7,608 38				27,608 38
1868	20,000 00		592 49				20,592 49
1869	20,000 00	$30,000 00	17,559 00	$58 96			67,617 96
1870	20,000 00		1,320 02	2,720 93			24,040 95
1871	18,250 00	10,500 00	4,135 72	3,785 54			36,671 26
1872	18,250 00	3,000 00	217 05	7,175 65			28,642 70
1873	21,796 00	15,602 00	10 13	11,059 06			48,467 19
1874	13,000 00	15,602 00	150 13	14,061 98			42,814 11
1875	7,638 00	7,755 50	144 53	14,446 14			29,984 17
1876	7,638 00	6,755 50	1,773 09	16,830 17			32,996 76
1877	6,150 00	30,686 80	979 06	15,172 86			52,988 72
1878	6,150 00	5,686 80	826 60	15,807 09			28,470 49
1879	4,971 80	16,068 32	712 22	16,978 22			38,730 56
1880	4,971 80	7,068 32	797 55	17,837 24			30,674 91
1881	7,249 00	43,720 50	461 95	20,935 25			72,366 70
1882	7,249 00	8,945 50	358 46	22,507 45			39,060 41
1883	8,385 00	23,793 00	391 95	30,749 60			63,319 55
1884	8,385 00	10,526 00	1,259 90	27,909 72			48,080 62
1885		35,103 00	187 50	29,770 40			65,060 90
1886		22,617 00		30,461 04			53,078 04
1887		*44,040 00	198 20	†24,611 37			68,849 57
1888		30,752 50	144 20	32,406 60	$15,000 00		78,303 30
1889		*20,973 00	10 50	31,322 69	15,000 00		67,306 19
1890		*27,172 00	238 50	32,360 64	15,000 00	$15,000 00	89,771 14
1891		22,947 50	37 38	34,750 54	15,000 00	16,000 00	88,735 42
1892		22,947 50	137 38	34,948 12	15,000 00	17,000 00	90,033 00
1893		18,862 50	10 50	37,927 04	15,000 00	18,000 00	89,800 04
1894		18,862 50	433 59	44,527 26	15,000 00	19,000 00	97,823 35
1895		‡19,000 00	10 50	45,301 85	15,000 00	20,000 00	99,312 35
1896		‡16,000 00		43,886 40	15,000 00	21,000 00	95,886 40
1897		§17,700 00		43,779 54	15,000 00	22,000 00	98,479 54
1898		‖17,500 00		47,508 28	15,000 00	23,000 00	103,008 28
1899		¶8,750 00	705 00	52,526 11	15,000 00	24,000 00	100,981 11
1900		¶72,500 00	175 00	72,298 38	15,000 00	25,000 00	184,973 38
1901††		¶72,500 00		63,976 79	15,000 00	25,000 00	176,476 79
1902	100,000 00	**1,000 00		64,081 81	15,000 00	25,000 00	205,081 81
1903	100,000 00	**1,000 00		65,573 90	15,000 00	25,000 00	206,573 90
1904	100,000 00	**1,000 00	61 19	67,312 37	15,000 00	25,000 00	208,373 50
1905	100,000 00	*81,000 00		72,035 32	15,000 00	25,000 00	293,035 32
1906	157,810 00	*15,000 00		70,286 56	15,000 00	25,000 00	283,096 56
1907	173,410 00	**1,000 00		70,155 22	23,691 60	25,000 00	293,256 82
1908	173,410 00	**1,000 00		70,385 79	23,326 10	30,000 00	298,121 89
1909	173,410 00	**1,000 00		69,527 13	26,000 00	35,000 00	304,937 13
1910	173,410 00	**1,000 00		71,109 49	28,000 00	40,000 00	313,519 49
1911	173,410 00	**1,000 00		70,304 15	30,000 00	45,000 00	319,714 15
Totals	$1,786,943 60	$827,937 74	$101,723 66	$1,631,170 65	$416,017 70	$545,000 00	$5,308,793 35

*Including appropriation for weather service.
†October 1, 1886, to June 30, 1887, nine months.
‡Including $5,000 for institutes and $1,000 for weather service.
¶Including $5,500 for institutes and $1,000 for weather service.
‖Incuding $5,500 for institutes and $1,000 for weather service
§Including $2,750 for institutes and $500 for weather service.
††To June 30. **Weather service.

SUMMARY OF INVENTORY, JUNE 30, 1910.

College farm and park, 671 acres		$67,100 00
Athletic field and drive, 13 acres		1,300 00
Buildings—		
Library and museum, built 1881	$22,000 00	
College hall, built 1856	17,000 00	
Wells hall, rebuilt 1905-06	55,000 00	
Williams, hall, built in 1869	30,000 00	
Abbot hall, built 1888, addition in 1896	15,000 00	
Chemical laboratory, built 1871, south end addition 1881	18,000 00	
Machine shops and foundry, 1885, south end addition 1887	15,000 00	
Veterinary laboratory, built 1885	5,000 00	
Horticultural laboratory, built 1888	7,000 00	
Agricultural laboratory, built 1889, imp. 1897	7,500 00	
Botanical laboratory, built 1892	10,000 00	
Armory, built 1885	6,000 00	
Greenhouse and stable, built 1873, 1879, rebuilt 1892 and 1902	6,000 00	
Boiler house and chimney, built 1893-4	3,000 00	
President's and two frame dwellings, built 1874	12,000 00	
Six brick dwellings, built 1857, 1879 and 1884	18,000 00	
One frame house, built 1885	3,500 00	
Howard Terrace dwelling, built 1888	13,000 00	
Farm house dwelling, built 1869	2,000 00	
Herdsman's dwelling, built 1867	400 00	
Six barns at professors' houses	1,050 00	
Horticultural barn and shed, built 1868, 1875 and 1877	1,200 00	
Bull barn, rebuilt 1905	1,500 00	
Sheep barn, rebuilt 1906	2,500 00	
Horse barn, built 1906	5,000 00	
Grade herd barn, rebuilt 1905	4,000 00	
Piggery, rebuilt 1907	1,500 00	
Dairy barn, rebuilt 1900	4,000 00	
Farm mechanics building, built 1881	1,500 00	
Poultry house, built 1906	1,000 00	
Incubator house, built 1906	500 00	
Poultry house, built 1907	1,500 00	
Three poultry houses, built 1907	300 00	
Ten brooder houses, built 1908	250 00	
Corn barn, built 1878	400 00	
Stock judging barn, built 1894	200 00	
Brick work shop, built 1857	500 00	
Observatory, built 1880	100 00	
Bath house and fittings, built 1902-3	17,000 00	
Paint shop, rebuilt 1903	150 00	
Hospital, built 1894	3,000 00	
Postoffice and waiting room, built 1902	1,700 00	
Lumber shed, mechanical department	250 00	
Three silos	600 00	
Coal shed, built 1899	700 00	
Women's building, built 1900	91,000 00	
Dairy building, built 1900	15,000 00	
Bacteriological building, built 1902	27,000 00	
Power house, built 1904	25,000 00	
Amount carried forward	$473,800 00	$68,400 00

Amount brought forward	$473,800 00	$68,400 00
Buildings—Continued.		
Coal shed, built 1905	6,500 00	
Tunnel system, built 1904	45,000 00	
Cold storage, rebuilt 1905	2,000 00	
Engineering building, built 1906-07, including heating	110,000 00	
Iron bridge over Cedar river, built 1888	1,500 00	
Bridge to athletic field	500 00	
Manure shed	600 00	
Four hospital cottages, built 1909	6,000 00	
Agricultural building, built 1909	182,000 00	
Addition to Botanical laboratory, built 1909	12,000 00	
		839,900 00
Heat, Light and Water Department—		
Instruments and furniture	$207 50	
Steam heating plant	15,890 00	
Bath house plant	698 00	
Water works plant	10,161 70	
Fire department	2,789 00	
Tools and fixtures	862 24	
Miscellaneous stock	4,663 98	
Electric light department stock	1,816 21	
Telephone department	3,511 71	
Plumbing stock	1,148 57	
		41,748 91
Agricultural Division—		
Department of Agricultural Education		443 32
Department of Animal Husbandry—		
Office library	$854 15	
Office	128 10	
Live stock	8,393 00	
Feed and miscellaneous	774 40	
		10,149 65
Department of Farm Crops		313 65
Department of Farm and Horses—		
Horses	$7,950 00	
Horse barn	1,310 89	
Corn crib	105 00	
Tool barn	1,703 88	
Office	334 20	
		11,403 97
Department of Farm Mechanics—		
Machinery and tools	$1,813 01	
Fittings	171 78	
Cement machinery	48 85	
Wood shop	623 73	
Blacksmith shop	1,081 62	
Office	165 69	
		3,907 68
Department of Forestry—		
Nursery stock	$8,517 30	
Forest products	144 80	
Office supplies	48 63	
Photographic materials	563 37	
Office furniture	446 85	
Nursery utensils	203 31	
Office equipment	65 00	
Laboratory supplies	134 67	
Camp equipment	261 00	
Books	609 20	
Exhibits	1,006 03	
		12,000 16
Amount carried forward		$988,267 34

Amount brought forward		$988,267 34
Department of Dairy Husbandry—		
Office	$462 50	
Live stock library	527 40	
Dairy live stock	7,249 00	
Feed	295 15	
Miscellaneous	68 00	
Dairy	1,365 30	
Dairy office	89 00	
		10,056 35
Office of Dean of Agriculture—		
Office	$565 69	
Classroom furniture	1,594 00	
		2,159 69
Department of Horticulture—		
Heavy tools	$516 00	
Teams and harness	725 50	
Miscellaneous	866 12	
Tools	232 40	
Office	1,487 55	
Classroom	399 75	
Laboratory equipment	508 32	
Greenhouse plants	1,453 30	
Greenhouse tools	222 09	
Zoo	100 00	
		6,511 03
Poultry Department		2,309 55
Department of Soils—		
General	$2,262 63	
Photographic supplies	119 44	
Chemicals	20 64	
Furniture	418 93	
		2,821 64
Short Courses		1,499 30
Department of Veterinary Science—		
General operating instruments	$464 98	
Office furniture and fixtures	185 12	
Harness equipment	17 13	
Laboratory equipment	181 68	
Drugs and chemicals	7 48	
Classroom apparatus	1,188 28	
Department books	31 53	
		2,076 20
Division of Engineering—		
Department of Civil Engineering—		
Transits	$4,258 05	
Levels	1,852 30	
Sextants	230 55	
Compasses	835 20	
Hand levels	225 95	
Pocket compasses	51 25	
Computing instruments	537 85	
Time recorders	670 20	
Barometers and thermometer	274 70	
Current meters	193 65	
Plane tables	449 65	
Leveling rods and poles	507 05	
Steel tapes	297 50	
Chains	53 00	
Metalic tapes	81 28	
Linen tapes	19 20	
Amount carried forward	$10,537 38	$1,015,701 10

Amount brought forward	$10,537 38	$1,015,701 10
Division of Engineering—Continued.		
Miscellaneous surveying instruments	252 70	
Drawing instruments and materials	436 84	
Books and pamphlets	284 60	
Tools	59 22	
Miscellaneous apparatus	494 44	
Furniture and fixtures	3,401 38	
Hydraulic laboratory	1,529 65	
Cement laboratory	1,619 55	
Astronomical laboratory	414 45	
		19,030 21
Department of Drawing and Design		5,304 76
Department of Physical and Electrical Engineering—		
Motors and generators	$5,888 00	
Wattmeters	528 00	
Voltmeters	678 00	
Ammeters	602 50	
Starting boxes	113 00	
Transformers	1,118 00	
Rheostats	162 50	
Miscellaneous	1,123 87	
Shop and stock	551 06	
Furniture	2,838 43	
Mechanics	1,336 15	
Electricity and magnetism	4,330 97	
Light	1,481 45	
Sound	170 70	
Heat	427 80	
		21,350 43
Department of Mechanical Engineering—		
Office supplies and equipment	$8,725 18	
Experimental laboratory	12,535 72	
Machine shop	9,465 09	
Foundry	1,653 99	
Forge shop	1,859 84	
Woodworking machinery and tools	3,513 30	
		37,753 12
Division of Home Economics—		
Reception room and hall	$672 60	
Dean's office	197 25	
Day student's room	218 50	
Parlor	638 30	
Guest room	62 85	
Dormitory furniture	1,725 41	
Miscellaneous	129 20	
Recitation room	3 10	
Storeroom No. 33	25 29	
Dark closet	27 10	
Music rooms	2,461 50	
House library	99 95	
Gymnasium	366 14	
Gymnasium office	146 03	
Shower bath rooms	187 35	
Domestic science	889 19	
Domestic art	961 25	
Howard terrace	422 52	
		9,233 53
Amount carried forward		$1,108,373 15

Amount brought forward		$1,108,373 15
Division of Science and Letters—		
Department of Bacteriology—		
Literature	$76 78	
College chemicals	983 37	
College apparatus	7,918 36	
Fixtures and office supplies	834 02	
		9,812 53
Department of Botany—		
Garden tools	$64 80	
Herbarium	11,391 80	
Museum	830 00	
Books	750 95	
Photos and engravings	1,125 53	
Lantern slides	264 24	
Microscopes and accessories	1,598 00	
Glassware	605 61	
Chemicals, stains, reagents, etc	63 45	
Office and classroom equipment	939 30	
General equipment	195 95	
		17,829 63
Department of Chemistry—		
Cases and fixtures	$2,917 35	
Graduated glassware	1,344 78	
Ungraduated glassware	5,221 67	
Organic chemicals	465 00	
Inorganic chemicals	896 81	
Electrical apparatus	974 73	
Special apparatus	3,195 35	
Gas analysis apparatus	165 00	
Platinum	2,044 42	
Mercury	21 25	
Balances	1,797 00	
Weights	797 70	
Metals	45 74	
Rubber	171 29	
Specimens and mineralogical supplies	586 72	
Porcelain	871 05	
Hardware	1,337 39	
Tools	64 90	
Woodenware	309 20	
Assay room supplies	214 54	
Miscellaneous	375 29	
		23,817 18
Department of English		725 44
Department of Entomology—		
Furniture and collections	$4,071 47	
Apparatus	691 42	
Books	141 79	
Supplies	299 23	
		5,203 91
Dept. History and Economics		484 40
Department of Mathematics—		
Office furniture	$196 95	
Books	44 58	
		241 53
Department of Military Science and Tactics—		
Military equipment	$898 50	
Band properties	77 75	
		1,674 25
Amount carried forward		$1,168,162 02

Amount brought forward		$1,168,162 02
Department of Physical Culture and Athletics—		
Armory and gymnasium	$453 00	
Bath house	40 40	
Office	201 00	
Field	133 10	
		827 50
Department of Zoology and Physiology—		
General museum	$18,868 00	
Furniture and apparatus	1,836 09	
Dissecting instruments	50 00	
Drawing instruments and materials	10 90	
Geological	243 79	
Microscopic	2,276 20	
Photographic	225 15	
Tools	59 28	
Miscellaneous	497 90	
		24,067 31
Carpenter shop		725 20
Cleaning		447 13
Farmers' Institutes Department		522 27
Hospital		261 93
Hospital cottages		611 75
Library		57,813 88
Department of Nursery and Orchard Inspection		80 43
Office of Registrar		333 30
Paint shop		646 28
President's office		873 58
Secretary's office		2,178 79
Miscellaneous		4,214 95
Weather Bureau		1,344 57
Total		$1,263,110 89

SUMMARY OF EXPERIMENT STATION INVENTORY.

Lands donated to the Station—		
80 acres at Grayling, fenced and improved at cost	$1,000 00	
5 acres at South Haven, fenced and improved	1,000 00	
160 acres at Chatham, including buildings	4,000 00	
		$6,000 00
Buildings—		
Bacteriological stable	$3,700 00	
Experiment station feed barn	800 00	
Veterinary laboratory, experimental rooms	250 00	
House	1,000 00	
Station Terrace building	3,000 00	
Seed room	500 00	
Slaughter house	625 00	
Storage barn	600 00	
Insectry	1,000 00	
		11,475 00
Experiment Station—		
Division of Bacteriology—		
Literature	$1,633 04	
Chemicals	652 63	
Apparatus	8,467 39	
Fixtures and office supplies	229 63	
		10,982 69
Division of Botany—		
Books	$15 80	
Glassware	43 38	
Chemicals	9 06	
Furniture	74 00	
Sundries	36 69	
General apparatus	206 62	
Miscellaneous	18 12	
Plants	344 00	
Microscopes, etc	320 62	
Photographic apparatus	183 79	
		1,252 08
Division of Chemistry—		
Chemicals	$420 01	
Glassware	1,045 11	
Porcelain ware	85 44	
Sampling material	188 08	
Office furniture and supplies	393 12	
Miscellaneous	2,970 33	
Tools	28 09	
		5,180 18
Farm Division		1,392 04
Division of Entomology—		
Furniture	$500 53	
Supplies	46 44	
Miscellaneous	1,762 58	
Books	711 70	
Apparatus	629 35	
Chemical supplies	214 24	
Amount carried forward	$3,864 84	$36,231 99

Amount brought forward	$3,864 84	$36,231 99
Division of Entomology—Continued.		
Photographic supplies	411 05	
Supplies	147 92	
Glassware	430 87	
Chemicals	185 87	
Stains	13 91	
Spray machinery	52 70	
Tools	19 82	
Sundry	94 12	
		5,221 10
Division of Horticulture		871 05
Library		4,703 50
Director's office		409 10
Bulletin room		425 76
Division of Soils		591 31
South Haven Experiment Station		256 15
Upper Peninsula Experiment Station		2,016 64
Total		$50,726 60

REPORT OF THE PRESIDENT.

To the Honorable State Board of Agriculture:

Gentlemen:—It gives me pleasure to be able to report a very prosperous year. Harmony has prevailed in faculty and student body. The general development incident to recent years has been maintained.

The enrollment of students was 1,568, an increase of 74 students over the previous year.

Commencement was held on June 22nd. The Baccalaureate sermon was given the preceding Sunday by Dr. Alfred W. Wishart, Pastor of Fountain St. Baptist Church of Grand Rapids, Mich. The Commencement address was delivered by Dr. James K. Patterson, President Emeritus of Kentucky University. The class numbered 128. Of this number 52 graduated from the Engineering course, 35 from the Agricultural course, 16 from the Forestry course and 25 from the Home Economic course. Their names and addresses are as follows:

NAMES OF GRADUATING CLASS.

The names and addresses of those receiving degrees are as follows:

(Students in Agriculture are designated by *a*; Engineering by *e*; Home Economics by h; Forestry by f.

Name.	Post Office.	County.
Anderson, Oscar Gustave, *a*	Shelby	Oceana.
Applin, John Wenner, *e*	East Tawas	Iosco.
Armstrong, Emerson Allen, *e*	East Lansing	Ingham.
Babcock, Leonidas Emile, *a*	Battle Creek	Calhoun.
Baker, Harry Lee, *f*	Saline	Washtenaw.
Baldwin, Ernest Wood, *e*	Midland	Midland.
Bates, Flora L., *h*	Moline	Allegan.
Bird, Marjorie Ida, *h*	Fremont	Newaygo.
Blust, John August, *e*	Tawas City	Iosco.
Bogue, Virgil T., *a*	Quincy	Branch.
Bradley, Marjorie MacBride, *h*	Park Ridge	Ill.
Brainard, Athol Edward, *a*	Onsted	Lenawee.
Brightup, Roscoe Ellsworth, *e*	Buchanan	Berrien.
Brown, Eugene Herbert, *a*	Detroit	Wayne.
Buck, Maurice M., *e*	Coopersville	Ottawa.
Caldwell, Ethel, *h*	Benton Harbor	Berrien.
Carpenter, Dwight Clark, *a*	Lansing	Ingham.
Carter, Herbert Marion, *e*	South Haven	Van Buren.
Chamberlain, Edna M., *h*	Lansing	Ingham.
Clark, Willard Bela, *e*	Kalkaska	Kalkaska.
Cleveland, Oliver Hedges, *e*	Adrian	Lenawee.
Clizbe, Ivan John, *e*	Quincy	Branch.
Collingwood, George Harris, *f*	East Lansing	Ingham.
Cortright, Ion John, *f*	Mason	Ingham.
Crane, U. S., *a*	Fennville	Allegan.
Curtiss, Charles Dwight, *e*	Camden	Hillsdale.
Dayharsh, Frank Cleveland, *a*	Hart	Oceana.
DeKoning, Jacob, *e*	Grand Rapids	Kent.
Dewey, George William, *a*	Bellaire	Antrim.
Dimmick, Guerdon L., *f*	Owosso	Shiawassee.
Dodge, Helen Elizabeth, *h*	Lansing	Ingham.
Duthie, Herbert Imlah, *e*	Grand Rapids	Kent.
Edwards, Ray Charles, *e*	South Frankfort	Benzie.
Eichele, Helen Marie, *h*	Lansing	Ingham.
Ellis, Ben Charles, *e*	Lansing	Ingham.

Names of Graduating Class.—Continued.

Name.	Post Office.	County.
Felton, Winifred Ethel, *h*	East Lansing	Ingham.
France, James Glenn, *a*	Coloma	Berrien.
Frazer, Elizabeth Jennie, *h*	Buffalo	N. Y.
Frey, Charles N., *a*	Caledonia	Kent.
Frutig, Albert, *f*	Detroit	Wayne.
Gibbs, Floyd J., *a*	Saginaw	Saginaw.
Goodell, Zelin Calvin, *f*	Lansing	Ingham.
Greenleaf, Myndret Charles, *e*	Onsted	Lenawee.
Hamilton, Charles Andrew, *e*	Grand Ledge	Eaton.
Hays, James Grant, Jr., *a*	Pittsburgh	PA.
Henrickson, Alfred, *a*	Shelby	Oceana.
Hewitt, Nina Bell, *h*	Okemos	Ingham.
Hilton, Huber Copeland, *f*	Fremont	Newaygo.
Holdsworth, Robert Powell, *f*	East Lansing	Ingham.
Hookway, William, *e*	Owosso	Shiawassee.
Itano, Aroa, *a*	Okayamaken	JAPAN.
Jeffery, Alice Elizabeth, *h*	Lansing	Ingham.
Jewell, Elton Lumns, *e*	Rockford	Kent.
Johnson, Ole Haakon, *e*	Lansing	Ingham.
Jones, Clifton Clement, *e*	Elmira	N. Y.
Kay, Tracy Howard, *e*	Detroit	Wayne.
Kedzie, Margaret Adella, *h*	East Lansing	Ingham.
Keith, Bert William, *a*	Sawyer	Berrien.
Kimmel, Zella Maud, *h*	Lansing	Ingham.
Knecht, John Wesley, *e*	Grand Rapids	Kent.
Knoblauch, Herman Fred, *a*	Blissfield	Lenawee.
Knopf, Carl Henry, *a*	Blissfield	Lenawee.
Kolb, Eugene Henry, *e*	Unionville	Tuscola.
Kopf, Evelyn Mary, *h*	Hastings	Barry.
Kurtz, Loren Grant, *e*	Flint	Genesee.
Langdon, Charles Samuel, *a*	Hubbardston	Ionia.
Lindemann, Edward Christian, *a*	St. Clair	St. Clair.
Lindsley, Louise Palmer, *h*	Harbor Springs	Emmet.
Linton, John Oliver, *a*	Otsego	Allegan.
Lossing, Frank, [illegible]	Fremont	Newaygo.
Lossing, Herbert Alfred, *e*	Fremont	Newaygo.
Lee, Leona Natalie, *h*	Flint	Genesee.
McCutcheon, James Herbert, *f*	Boyne City	Charlevoix.
McKibbin, Clifford Worden, *f*	Lansing	Ingham.
McNaughton, Edna Belle, *h*	Middleville	Barry.
McVittie, Alexander, *e*	Ypsilanti	Washtenaw.
Newton, Walter Alfred, *e*	Kalamazoo	Kalamazoo.
OcKada, Charles Junzo, *a*	Iwo	JAPAN.
Olmstead, William Ray, *e*	Freeland	Saginaw.
Osborne, Gurdon Hoard, *e*	Detroit	Wayne.
Palm, Elizabeth Myrtilla, *h*	East Lansing	Ingham.
Parmalee, Mae Villa, *h*	Scottville	Mason.
Pennington, Mary Bertha, *h*	Grand Rapids	Kent.
Perham, Stanley Harrison, *e*	Kent City	Kent.
Perrin, Stephen William, *e*	Pittsford	Shiawassee.
Peterson, Harry Samuel, *e*	Lucas	Missaukee.
Porter, Benj. Church, Jr., *a*	Grand Rapids	Kent.
Powell, Ralph Waterbury, *e*	Ionia	Ionia.
Pratchner, William Wells, *a*	Santa Cruz	CALIFORNIA.
Richards, Fred Jerome, *e*	Lansing	Ingham.
Robison, Mabel Margaret, *h*	Cass City	Tuscola.
Roe, Clarence Sage, *e*	Lansing	Ingham.
Rork, James Estin, *e*	Lansing	Ingham.
Rose, Charles Lovell, *a*	Evart	Osceola.
Sauve, Edmund Chester, *c*	East Tawas	Iosco.
Schaeffer, Vern Clifford, *a*	Sturgis	St. Joseph.
Schneider, Elizabeth Helen, *h*	Lansing	Ingham.
Schubach, Edward George, *e*	Pigeon	Huron.
Scott, Leo Blynn, *a*	Hersey	Osceola.
Severance, Clare Sullivan, *a*	Fenton	Genesee.
Shanor, William Wolf, *a*	Pittsburgh	PENNSYLVANIA.

Names of graduating class.—Concluded.

Name.	Post Office.	County.
Sloss, Ralph Wilcox, *f*	Big Rapids	Mecosta.
Smith, Guy Harmon, *e*	Detroit	Wayne.
Springer, George Percy, *e*	Whitehall	Muskegon.
Sproat, Will Jay, *f*	Grand Rapids	Kent.
Steck, Edward William, *e*	Three Oaks	Berrien.
Taft, Howard Austin, *a*	East Lansing	Ingham.
Tappan, Emory Wesley, *e*	East Lansing	Ingham.
Thomas, Charles Peach, *e*	South Ryegate	VERMONT.
Tillotson, Fred Howard, *e*	Elsie	Clinton.
Trautman, Ethel, *h*	Wayland	Allegan.
True, Frank Lathrop, *a*	Armada	Macomb.
Tubergen, Charles Burton, *a*	Grand Rapids	Kent.
Urqhart, William Henry, *e*	Detroit	Wayne.
Van Horne, Neil, *f*	Marquette	Marquette.
Wales, Henry Basil, *f*	Elkton	Huron.
Walker, Louis Pauly, *e*	St. Ignace	Mackinac.
Wallace, Edwin Earl, *e*	Albion	Calhoun.
Walker, Walter Rae, *e*	Detroit	Wayne.
Wandel, Edwin Phillip, *e*	Grand Rapids	Kent.
Warmington, George, *e*	Houghton	Houghton.
Watts, George Elwin, *a*	Alto	Kent.
Whyte, Thomas Callin, *e*	Detroit	Wayne.
Wilson, Frederick Grover, *f*	Plymouth	WISCONSIN.
Wilson, Iva A., *h*	Grand Rapids	Kent.
Williamson, Hannah, *h*	Ludington	Mason.
Wood, Devillo Demic, *f*	Lansing	Ingham.
Wright, Edward Farrand, *a*	Detroit	Wayne.

COUNTIES REPRESENTED IN ENTERING CLASS.

Allegan	7	Leelanau	1
Antrim	4	Lenawee	13
Barry	3	Livingston	6
Bay	4	Macomb	2
Benzie	3	Mackinac	4
Berrien	10	Manistee	3
Branch	3	Marquette	2
Calhoun	8	Mason	4
Charlevoix	4	Mecosta	1
Cheboygan	3	Menominee	2
Chippewa	1	Missaukee	1
Clinton	11	Midland	1
Delta	1	Montcalm	2
Dickinson	3	Muskegon	1
Eaton	9	Monroe	1
Emmet	3	Oakland	11
Genesee	9	Oceana	6
Gogebic	2	Osceola	5
Grand Traverse	7	Oscoda	1
Gratiot	5	Ottawa	8
Hillsdale	5	Presque Isle	1
Houghton	5	Saginaw	6
Huron	8	Sanilac	2
Ingham	63	St. Clair	4
Ionia	6	St. Joseph	1
Iron	1	Shiawassee	10
Isabella	3	Tuscola	1
Jackson	8	Van Buren	8
Kalamazoo	9	Wayne	51
Kalkaska	1	Washtenaw	5
Kent	23	Wexford	4
Lapeer	5		

Other States and Countries represented.

Connecticut	3	New Hampshire	1
China	3	New Jersey	4
Delaware	1	New York	22
Illinois	9	Ohio	2
Indiana	3	Ontario	1
Kansas	1	Pennsylvania	14
Massachusets	3	Russia	4
Mexico	1	Texas	1
Minnesota	1	Tennessee	1
Mississippi	1	Washington	2
Montana	1	Wisconsin	1

STATISTICS OF ENTERING CLASS.

	Men.	Women.	Total.
Number entering	389	97	486
Average age	19.8	18.9	19.3
Schools:			
High	305	91	396
District	3		3
College	35	2	37
State Normal	11	2	13
Private	8		8
State University	19	2	21
Technical	8		8
Support while here:			
Parents	192	81	273
Self	125	7	132
Parents and self	56	4	60
Other Sources	16	5	21

CHURCH MEMBERSHIP.

Denominations.	Members.	Preference.	Total.
Baptist	30	23	53
Church of Christ	2		2
Church of Christ Science		1	1
Congregational	29	35	64
Disciple	5		5
Episcopal	25	11	36
Evangelical	2	1	3
Friends		1	1
German Methodist		2	2
Hebrew	5	2	7
Lutheran	10	3	13
Methodist Episcopal	64	54	118
Methodist Protestant		1	1
No preference		65	65
Presbyterian	47	25	72
Presbyterian (United)	1		1
Roman Catholic	31	2	33
United Brethren		1	1
Unitarian		2	2
Universalist	3	3	6

SUMMARY OF STUDENTS.

	General Agr'l.	Cream'y.	Poultry.	Fruit.	Cheese.	Agricultural.	Engineering.	Home Economics.	Forestry.	Veterinary.	Total.
Graduate students						3	1	1	2	......	7
Class of 1911						40	58	26	21	......	145
Class of 1912						57	76	35	18	......	186
Class of 1913						91	130	48	21	5	295
Class of 1914						159	172	100	......	......	431
Sub-Freshmen						76	40	19	......	......	135
Special students						35	4	7	4	......	50
Special short course students	208	58	10	40	5	321	......	......	......	......	321
Totals						782	481	236	66	5	1,570
Deduct names repeated											2
Net total											1,568

The college lost a very useful man in the resignation of Chester L. Brewer, Prof. of Physical Culture and Director of Athletics. Mr. Brewer was with the college about seven years and during that time he brought his department to an unusually high degree of efficiency. His quiet and sane method of dealing with students won for him a warm place in their affections, and his high standard of morals as exemplified in his daily life has no doubt had a lasting influence for good on the lives of a large number of young men. He resigned to accept a similar position with greater responsibility and a much larger salary in the State University of Missouri.

Mr. John F. Macklin, a University of Penn. man, who has had charge of athletics in the Pawling School, New York, succeeded Mr. Brewer in January and has already given ample evidence of his fitness for the position.

The needs of the college are much the same as set forth in previous reports. Our library, on account of lack of room, does not render half the service to the student body that it should, to say nothing of the constant danger of fire.

The college has no meeting place for students except the old chapel and the armory. The chapel will seat about two hundred fifty people or less than twenty per cent of the student body. The armory is needed every day for other purposes as it serves for a drill hall, gymnasium and place for social affairs. It requires considerable work to make the room ready for a meeting. Because of the lack of a suitable auditorium

it has not been felt advisable to try to carry on a lecture course this year. It is greatly to be regretted that the college is not able to give its students the opportunity to hear some of the orators of national reputation.

The last Legislature, appreciating the great need of better library and auditorium facilities, voted one hundred fifty thousand dollars for the erection of such a building, but the Governor interposed his veto and the measure, greatly to our regret, failed.

In addition to a library and auditorium the college should have at once a gymnasium, an additional wing to the woman's building and more dormitories.

The financial needs of the college are not confined, however, to the funds necessary to erect new buildings. There is a very strong call now from the farmers of the state for more help from the college. They ask for more institutes, more demonstration trains, more speakers for meetings and for more help in various other ways. They are insisting on more extension work on the part of the college. This movement is quite general throughout the country and a number of states have responded by making large appropriations for traveling schools as well as for other forms of extension work.

The college should meet the call from the farmers and inaugurate as soon as the funds can be provided, a system of traveling schools which will carry to the farmers of each county much of the practical instruction now given at the college to short course men.

Our department of Agricultural Education has succeeded in having fifteen high schools in the state organize agricultural departments. These departments are in charge of graduates from the college. The work given is very helpful and is very much appreciated by the patrons. A number of other schools will organize such departments next year.

There must, and will be, a great onward movement along all lines of agricultural education within the next few years. The work has just begun. The agricultural colleges and experiment stations must be the leaders in this great movement. They should assume the leadership and by aggressive effort maintain it. If they are not ready to meet the great demands made upon them independent movements will spring into being which though good in themselves will be much less effective than if directed by a central organization. This college will need during the next few years in order to meet the responsibilities placed upon it greater financial support than it has received in the past. The college has the confidence of the people of the state and it is believed that if they realize the needs of the college, financial support will not be lacking.

For information concerning the work of the various departments of the college, please consult the reports in the following pages.

J. L. SNYDER,
President.

East Lansing, June 30, 1911.

REPORT OF THE DEAN OF AGRICULTURE.

To President J. L. Snyder:

During the year no changes occurred among those in charge of the departments of the agricultural division and the same is also true of assistants and instructors with but one or two exceptions. The future success of the division must depend largely on retaining the services of the present efficient staff. The organization seems to be well adapted to meet the demands made upon it both in educational work at the college and in extension work in the state. There is great need, however, for the establishment of extension work along dairy lines intended to aid in the improvement of the quality of the dairy products of the state.

The office of the Dean and Director has received very satisfactory aid from the assistance rendered by Mr. R. J. Baldwin, whose services were procured January 1st, 1911.

The department of Farm and Horses is operated jointly by the Dean of Agriculture and the Farm Superintendent. A separate report of this work has not been prepared as it is the intention to issue a financial statement relative to the crops produced covering three years past. This department endeavors to produce food stuffs as far as possible for those with live stock equipments and also to furnish the necessary team labor. In addition to this it included the control of the horse breeding operations, represented by fourteen registered Percherons and five Clydesdales.

The work of nearly all departments of the agricultural division may be given a triple classification viz.: education, experimentation and extension. Only three of the ten departments receive moneys from federal appropriations for experimentation. The work in horticulture and crops is maintained in part from Hatch funds while soil investigations receive support from the Adams bill revenues. Small portions of the salaries of six department heads are defrayed from experiment station funds. This therefore means that the farm crops and live stock producing departments are reliant on current college funds for the performance of their triple functions. As the three lines of work named are non-revenue producing it necessarily follows that much larger appropriations are necessary than would be the case if the departments were being merely maintained or operated on a commercial basis. An attempt has been made to develop the various departments uniformly and symmetrically as illustrated by the standards acquired in the case of poultry, swine, sheep, beef and dairy cattle and horses. The maintenance of a number of breeds for educational purposes is costly as illustrated in the sheep equipment where there are now eight distinct flocks necessitating separate breeding, feeding, yarding, pasturage etc. In handling a commercial sheep equipment there would be but one flock, one ram, one by-pen, one yard and one pasture in use at a time thus reducing the cost many times over. We believe a strong live stock equipment should be maintained and with the triple demands on it liberal financial support is needed.

Heretofore the forest nursery work has been scattered in various places on the lands under the supervision of the forestry department, some of the work having been fully one and one-half miles distant from the college buildings. In order to economize as regards labor and locate the nursery work within easy access of the student and visitor field No. 6, located just across the Cedar River, has been turned over to the forestry department for nursery work. In return for the tract which comprises about 29 acres, lands hitherto used for forestry purposes located between the Pere Marquette Railroad and the Mt. Hope Avenue Road have been turned over to the farm department. During the past winter nearly all the straggling timber was removed from the tract and made into wood or lumber.

On June 19th, a four weeks summer school in practical agriculture was opened with about fifteen young men in attendance. The object of this special course is to give young men from villages, towns and cities lacking in farm experience, an opportunity to learn how to do all kinds of farm work in the most efficient manner, though the time allotted is not expected to produce skillful laborers. Those who have not been trained on well operated farms are required to take this course before graduation.

The following is a statement of the number of students enrolled in the agricultural division during the year:

Students enrolled during 1910-11 in Agriculture and Forestry.

Post Graduates	5
Seniors	61
Juniors	75
Sophomores	112
Freshmen	159
Sub-freshmen	76
Specials	39
	527

Special Short Course Students, Winter Term, 1911.

General Agriculture, first year, eight weeks	157
General Agriculture, second year, eight weeks	51
Creamery, first year, six weeks	52
Creamery, second year, six weeks	6
Cheese, four weeks	5
Poultry, eight weeks	10
Fruit growing, four weeks	40
	321

The one week courses in corn growing, poultry raising and dairying were well attended and much interest was manifested.

The following is a statement of the work of Mr. W. F. Raven, Live Stock Field Agent who was also employed part of the time in other phases of agricultural extension work:

"Beginning in July, I completed the Agricultural Soil Survey of

Roscommon County, going over every section of 12 townships, writing a description of each section and where the soil varied in composition, samples of soil were taken, labeled, numbered and sent to the soils department for analysis. Prof. J. A. Jeffery spent three days with me taking photographs of the homes, both occupied and abandoned, in township 24 north, range 2 east, and advising me in the classification of the soils and comparisons of classifications. Mr. O. K. White spent four days in determining the horticultural possibilities of the section surveyed. Prof. A. J. Patten spent three days advising as to the classification of soils and methods of taking soil samples. Altogether 13 of the 16 townships that comprise Roscommon county have been surveyed. The following remain unsurveyed, viz.: township 21 north, 2 west is owned by a corporation known as the "Milwaukee Fruit Farm." Townships 21 north, 3 and 4 west, are forest reserves.

I looked over 37 sections of land for the Antrim Iron Co., in Antrim and Kalkaska counties; 950 acres for Harrison M. Parker, in Muskegon county. September 12, I gave a lecture at Bean Jobbers' Convention at Saginaw. Attended State Fair three days with college exhibit. Gave lecture at Harrisburg, Pa., before Pennsylvania Live Stock Breeders' Association, topic 'Michigan Methods of Live Stock Improvement.' Attended the National Corn Exhibition at Columbus, Ohio, during its session and while there gave two lectures, one at the Ohio State University before Short Course students, the other before College Extension workers at the corn show, the topic in both places was 'Michigan Method of Live Stock Improvement.' I also attended the National Dairy Union at Chicago (at my own expense) and gave a lecture on same.

I have organized Breeders' Associations at the following places: Long Rapids, Alpena county; Adrian, Lenawee county; Grand Rapids, Kent county; Barrytown, Mecosta county; Shelby, Oceana county and assisted in the organization of Central Michigan Holstein Breeders' Association at Lansing. I have attended the one-day institutes in Isabella, Sanilac and Ingham counties; the two-day institutes in Montmorency, Cheboygan, Emmet, Wexford, Lenawee, Washtenaw and Ingham counties, besides accompanying the institute train one week. Have given lectures at the High School of Saline and Watervliet and judged corn at the Boys' Corn Growing Contest, at Muskegon. I have visited every farm in Columbia township, Jackson county, and collected the farm statistics of each farm.

I have visited the following places in the interests of better live stock and in nearly every place have held one or more meetings as indicated, with an attendance of from 18 to 80 farmers: McBrides, 3; Traverse City, 3; Vandalia, 1; Jones, 1; Grand Rapids, 3; Barryton, 3; Mecosta, 1; Remus, 3; Missaukee Junction, 2; Cadillac, 2; Long Rapids, 2; Lachine, 1; Defoe, 2; Trenton, 1; Kalamazoo, 1; McGregor, 1; Argyle, 1; Bay Shore, 1; Manton, 1; Morley, 1; Stanwood, 1; Big Rapids, 1; Sand Lake, 1; Shelby, 1; New Era, 1; Kaleva, 1; Bellaire, 1; Alden, 1; Bendon, 1; Alpena, 2; Hillman, 1; Mt. Pleasant, 1, and Beal City, 1. I have visited 379 farms, the owners of which had 2,520 cows of which 52 were registered and 488 were being bred to registered sires. I have established three herds of pure bred cattle; Joseph Bowden, Alpena, Geo. M. Brooks, Manton and E. M. Lamos, Barryton. Among the 2,520

cows I have placed 32 registered sires, that is, the owners of cattle have agreed to purchase the sires. They have not in all cases purchased them as yet, but are negotiating with parties for their purchase. I have organized nine Alfalfa Clubs, viz.: Melvin, Carsonville, Leslie, Wolverine, Harbor Springs, Atlanta, Hillman, Manton and Weidman. Have looked over about 90,000 acres of cutover hardwood land in Cheboygan county with Mr. A. B. Segur, of Indianapolis, Ind., for the purpose of opening them for agriculture.

I have attended the annual convention of the Federation of Operative Millers' of America, at Detroit with the Station exhibits of wheat, flour and bread. During the year, I have visited several of the Breeders' Associations that I have organized and with the exception of two (Jones and Traverse City) all are in a prosperous condition and doing good work. The two mentioned are still using the Association methods of work, but have surrendered their corporate charter. This was the result of disagreements among the members of the Association. Four weeks were spent with the short course students, June 19 to July 1st, 1911."

Respectfully submitted,
R. S. SHAW,
Dean of Agriculture.

East Lansing, June 30th, 1911.

REPORT OF SOILS DEPARTMENT.

President J. L. Snyder, College:

Dear Sir: During the year just closed this department has given instruction to something like 375 students of all grades. This number would be increased by at least 150 if it were not for the changing of the schedule, which has thrown several of our classes farther ahead in our course.

It is a pleasure to report that along all lines, we have been enabled, as predicted in our report of a year ago, to enlarge and make more practical the different courses which we are offering the students. This is due to the better facilities offered by the new building for such work and also to its influence upon the spirit of the student body.

Mr. Spurway has done excellent service as instructor and is responsible in no small measure for the enlargement of the work.

A new departure this year was a trip of inspection to six typical farms of Michigan. The results were so gratifying that it is planned to make this feature a permanent part of the work for the future. The inspection of these farms gave to the students a better conception of the possibilities of the farm, as well as of the importance of correct management.

As usual there has been a large demand for extension work, so large indeed that we were unable to respond to all the calls made for help in this direction. These calls came from the State Teachers' Association;

high schools of the state; the farmers institutes; boys' corn growing contests; county Y. M. C. A.'s; normal schools; county commissioners, etc.

Respectfully submitted,
JOS. A. JEFFERY,
Professor of Soils and Soil Physics.

East Lansing, June 30, 1911.

REPORT OF THE DEPARTMENT OF DAIRY HUSBANDRY.

To the President:

The instructional work in dairy production has been given during the past year as scheduled in the catalogue, in connection with the class work of the animal husbandry department.

A keen interest in this work has been apparent throughout the year and while the classes were exceptionally large we feel that the year just closed has been quite successful.

During the fall term 17 seniors took the work in Creamery Butter Making and in the spring term instruction was given in Farm Dairying to 87 sophomores.

The past winter the two special courses in Creamery Management were each extended two weeks making the first year course eight weeks in length and the second 6 weeks.

The number of men instructed in the special courses is as follows:

First year creamery	53
Second year creamery	6
Cheese making	5
Farm dairying	51

The increasing number of factories making butter from gathered cream and the difficulties encountered in the manufacture of butter from gathered cream have necessitated a marked change in the instructional work of the creamery courses, both in the purchase of raw material and in the methods of manufacture.

Each year the number of inquiries for men with dairy school training to fill positions in creameries and other dairy plants has increased so that every man wishing employment during the past year has secured steady work.

A large part of the instructional work in dairy manufacture has been done by Instructor W. B. Liverance, assisted during the special courses by Messrs. Simon Hagadorn, Charles Dear and Robert F. Hopkins, to all of whom we are indebted for efficient work.

During the year 18 old stalls in the dairy barn were replaced by modern sanitary ones. The herd has improved by the growth of the comparatively large proportion of young cows and heifers included within its number. All of the animals under semi-official test for yearly

records completed their requirements with very creditable margins, and a number of superior seven day official records were made.

All the members of the herd are tested each year for tuberculosis. The number of reactions secured from year to year has been steadily decreasing. This year we are pleased to report that none of the dairy animals responded to the test.

The equipment of barns and cattle for dairy production is comparatively satisfactory, but we are compelled to report that the present building used for dairy manufactures is inadequate and poorly adapted for the purpose. During the past year we have been compelled to hold classes in milk separation and in Babcock testing in portions of the basement.

This basement is little more than a cellar and was never designed to be used for any such purpose. We are trying to make the best of the situation, but until some more adequate and sanitary structure is available for the dairy manufactures work that portion of the department must suffer serious handicap.

Respectfully submitted,

A. C. ANDERSON.

REPORT OF THE DEPARTMENT OF HORTICULTURE AND LANDSCAPE GARDENING.

To the President:

Sir: I have the honor to submit the following report of the department of Horticulture and Landscape Gardening for the year ending June 30, 1911.

There have been no changes nor irregularities in the class work during the year. Classes in all subjects have been larger than in any previous year. This is especially so of the elective work which begins in the fall term of the junior year. This increase in the number of students electing the technical work, emphasizes the need for additional equipment, and one of the most urgent needs is for a new range of greenhouses. The present houses are not suited for purposes of instruction. A range of several houses should be erected in the rear of the laboratory where they will be near the class rooms and gardens.

These greenhouses are needed for the laboratory work of the following classes:

Fall Term for Seniors in Plant Breeding.

Fall Term for Junior and Senior Women in Floriculture.

Winter Term for Juniors in Greenhouse Industry.

Winter Term for Sophomores in Plant Propagation.

Spring Term for Thesis work for part of the Seniors.

Spring Term for Sub-freshmen part of the term in Vegetable Gardening.

The lack of this equipment is a serious one for the department and ranks us behind other colleges and universities that we have to compete with in training students. It is hoped that provision can be made at an early date to erect these houses.

Each year our experience indicates that it is wise to continue our efforts to increase and strengthen the technical work at the expense of what might be called a popular presentation of the subject matter. If our graduates are to successfully compete with those from other colleges and universities in commercial and scientific work, we must make every effort to have them thoroughly trained in the underlying fundamental principles of the art and science of the subject. The practical application is very largely a matter of time.

Plantings on the campus to increase the varieties of trees and shrubs, have continued. This is desirable for the general appearance of the campus and especially to provide living material for class instruction in the landscape gardening and other courses.

A continued effort is being made to add to the attractiveness of the gardens and orchards. The greatest demand seems to be to increase the fertility of the soil and this is being done as rapidly as possible in every practical way.

The extension work of the department is meeting with splendid encouragement in all the fruit growing sections and in many others where the farmers have shown a disposition to care for their orchards or make new plantings.

Early in the spring, arrangements are made for a series of meetings in communities where the demand is the greatest. These meetings are not of the lecture kind but are held in orchards and the people are instructed by observing the actual operation performed before them. The first meeting in the series, held early in the spring, would be on pruning, and spraying for scale. The others would be on the early foliage spraying; cultivation; thinning and later sprayings; cover crops and packing. In addition to these demonstrations, a large number of other meetings are held as time permits and the season demands.

The usual number of farmers' institutes and high school meetings were attended by members of the department who took an active part in them.

Exhibitions were also made at the State Fair at Detroit and the West Michigan Fair at Grand Rapids.

The spirit of cooperation that has existed between all members of the department for the advancement of the work, continues and I again have the pleasure in recording the work of Assistant Professor C. P. Halligan, Instructors Thomas Gunson and O. I. Gregg, Field Agent in Horticulture O. K. White and Foreman A. Davis has been thoroughly satisfactory.

Respectfully submitted,
H. J. EUSTACE,
Professor of Horticulture.

East Lansing, June 30, 1911.

REPORT OF THE DEPARTMENT OF POULTRY HUSBANDRY.

President J. L. Snyder, East Lansing, Mich.:

Dear Sir: The instructional work of the poultry department has been unusually successful, there being greater numbers in the classes and exceptional interest.

For the regular senior work, five men enrolled in Agriculture 5 b, twenty-seven in Agriculture 5 c, and twelve in Agriculture 5 d; one hundred twenty sophomores took the poultry work given as a part of Ag. 1 a; 55 juniors the work given as a part of Ag. 3 a; fifteen completed the special eight weeks course in poultry, and twenty-five enrolled for the one week course, thus making a total enrollment in poultry work for the year of 242 men, not including the general short course agricultural students who were given two weeks of lecture work.

A new feature was introduced in the way of a Poultry Institute or one week course in poultry raising, regular classes being held each morning with meetings in the afternoon and evening.

8:55 to 9:50, Housing and Yarding, H. L. Kempster.

9:50 to 10:45, Incubating and Brooding, J. L. Nix, Pres. Prairie State Inc. Co.

10:45 to 11:40, Feeding and General Care, Prof. W. R. Graham, O. A. C.

Tuesday: 1:30 p. m., Poultry Diseases, Dr. C. E. Marshall, Dr. F. W. Chamberlain, J. O. Linton.

7:00 p. m., Keeping Poultry on a City Lot, John Dubois.
Incubating, J. L. Nix.

Wednesday:

1:30 p. m., Poultry Judging, James Tucker.

7:00 p. m., Canadian Marketing, Prof. W. R. Graham.

Thursday:

2:00 p. m., Chalk Talk on Breeds, Franklane L. Sewell.

7:00 p. m., Conditions of Table Poultry on the European Markets, F. L. Sewell.

The work was given as a part of the eight weeks short course, thus affording these students an opportunity of meeting some of the most prominent poultry men, and although only twenty-five enrolled there was an average attendance at the meetings of seventy-five people.

The annual college poultry show was held at this time, with a greater variety and better quality than in previous shows and for the first time it was considered unnecessary to enter college birds for display.

Aside from the instruction work at the college more people in the state have been reached. The demand for poultry judges at the county fairs has been unusual and the several exhibits judged have afforded the department an opportunity to come in contact with those most interested. The sending of speakers to the various high schools and institutes has also assisted in creating an interest in better poultry and

the institute train work served as a means whereby the department was enabled to determine the needs of a greater number. A larger effort should be made to come in contact with the farming classes and endeavor to cause them to appreciate the necessity and desirability of better care of farm poultry and poultry products.

The experimental work on the comparison of houses has been continued and a report is being prepared. This part of the poultry department work has been neglected because of the heavy instructional duties. More attention should be paid to poultry experimentation and demonstration, and it is the hope that this work will be encouraged by special help and equipment in order that the departments influence may extend beyond the instructional work to the complex problems of the poultry man.

The equipment has remained unchanged. About 1,300 young have been raised to replace the old and there will be a greater variety thus making the flocks more adaptable to student work.

It has been very difficult to properly equip a man for poultry work in the past because of lack of time. Also some of the agricultural courses have been criticized because of lack of poultry instruction. In order to correct these two conditions a change in courses has been made. All poultry work is to be given in the junior and senior year, the junior work being required of all agricultural students, viz.: origin, history, and characteristics of the more common breeds of poultry as a part of Animal Husbandry 3; the Feeding of Farm Poultry as a part of Animal Husbandry 4, and Elementary Poultry Raising as an independent subject in the spring term. The senior work is more advanced. By this arrangement the agricultural student is given a general course in poultry raising and the poultry specialist will have a year's preparation, thus enabling him to do more satisfactory and thorough work.

The department feels the need of more room. Crowded conditions are not conducive to thorough work. The use of a room in the Agricultural Building for a laboratory greatly relieved conditions during short course, but the use of temporary quarters is unsatisfactory, due to the impossibility of securing and of maintaining permanent equipment. Classes in poultry judging were held at the poultry house and this building was inadequate because of the large number. The practice work in poultry feeding must undergo a change. With the large numbers taking the work, under present arrangements it has been necessary to let students use the breeding pens, a practice unfavorable to best results in production or in the hatching and raising of the young. The introduction of partitions into some of the pens in the long house will make it especially adaptable for student work without interfering with its present usefulness.

Considerable credit must be given Mr. J. O. Linton who assisted in the short course work, and it is a pleasure to report that his work was highly satisfactory.

The necessity for more extension work and the encouragment of more poultry experimentation cannot be over emphasized and provisions should be made to efficiently handle the increasing numbers in the various courses. It is only by the development of all these activities that

the poultry department can realize its hope that the people of the state be brought to an appreciation of the importance and possibilities of poultry on the farm and the necessity for better methods in its care.

Respectfully submitted,
H. L. KEMPSTER,
Instructor in Poultry Husbandry.

East Lansing, June 30, 1911.

REPORT OF THE DEPARTMENT OF FARM MECHANICS.

To President J. L. Snyder:

Dear Sir: In submitting the following report we wish to express appreciation of the willingness and zeal shown by the men who have assisted in the work of the department for the past year.

Mr. A. Watt, instructor in blacksmithing, has raised materially the standard of work done and has satisfied the numerous demands for repair work by other departments with unusual promptness.

Mr. F. Fogle who was engaged for the short course work in wood shop, consented to finish the school year as a regular instructor. His practical experience in carpentry and as a teacher has well fitted him for this work. We are also indebted to him for additional assistance rendered in the laboratory work in Farm and Power Machinery.

Mr. J. Houghtalling and Mr. W. Sizer assisted in the laboratory and shops through the Short Course.

Within the last year the forge shop has been enlarged for convenience and nine new forges were added to meet the requirements of the large number of men taking work in the short courses. The work in Power Machinery has been facilitated by the addition of a new five horse-power automatic steam engine, and a larger number of gasoline engines which have been placed upon a convenient stand having an exhaust chamber to take care of objectionable gases.

The courses in Power and Farm Machinery have been divided and can now be given to much better advantage. A new course in Farm Construction has been planned which it is hoped will meet the need for instruction along this line and furnish a fund of information for those seeking advice in this branch of farm engineering. It is hoped that much time can be given to the development of this work and to the improvement of the instruction in Farm Machinery which is not yet on a satisfactory basis owing to lack of equipment and a well proven course of study.

Respectfully submitted,
H. H. MUSSELMAN,
Instructor in Farm Mechanics.

East Lansing, Mich., June 30, 1911.

REPORT OF THE DEPARTMENT OF FARM CROPS.

President J. L. Snyder:

I submit herewith the following report of the department of Farm Crops, for the year ending June 30, 1911.

During the fall term, instruction was given to eight students in Advanced Grain Judging, Agr. 12c. During the winter term, instruction was given to 157 freshmen and 98 sophomores in Cereal Crops, Agr. 12a and to 164 1st Year Short Course men in Crop Production and 53 2nd Year Short Course students in Grain Judging, making a total of 480 students during the year. Owing to the recent revision of the agricultural course and the lack of instructors, no senior elective courses were given during the winter and spring terms. During the week, January 16 to 21, 1911, a week's course in Corn Production was offered, the morning programs being devoted to various subjects relating to corn production by members of the College and Station staff and specialists from other states, and the afternoons being devoted to Corn Judging, under the instruction of Mr. J. P. Prigg, of Daleville, Ind.

The department is now provided with commodious quarters which are well suited to the needs of the department. The necessary laboratory tables, and cupboards for equipping the laboratories as well as some scientific apparatus were purchased during the year.

The special need of the department as regards equipment, however, is an adequate supply of charts, illustrations, etc., providing a fund of agricultural data applicable to Michigan conditions. Work has begun on the preparation of this material but much time and study will be required to acquire an adequate supply.

Respectfully submitted,
V. M. SHOESMITH,
Professor of Farm Crops.

East Lansing, June 30, 1911.

REPORT OF THE DEPARTMENT OF ANIMAL HUSBANDRY.

President J. L. Snyder, East Lansing, Mich.:

Dear Sir:—The instruction work during the past year has been given as outlined in the catalogue. During the year 612 men were enrolled in the seven courses and were instructed in ten classes, making an average of 61 men in each class. This number can easily be handled in the lecture room, but in the judging pavilion where the class should do practical judging work, it is nearly impossible to give the class more than a demonstration, as 60 men cannot work on one ring of animals, which is all that can be handled by one instructor. It is sincerely hoped

that the necessity for dividing classes will become apparent, and sufficient help be provided so that this can be done in the near future.

Last fall term marked the beginning of the new course, and the uniformly high grade of work done by the 178 freshmen enrolled in Ag. 1 gave unmistakable evidence that the change was a wise one.

In Ag. 1b, a study of the breeds of sheep and swine, 125 sophomores were enrolled, and, considering the fact that many members of the class had already elected to take the forestry and horticultural courses. very satisfactory work was done.

Nineteen seniors elected the animal husbandry work and received practical judging work during the fall term.

The winter term's work was devoted largely to the teaching of short course men, 163 first year men receiving instruction in the breeds of live stock and 54 second year men in practical judging work.

Aside from the short course men 63 sub-freshmen received instruction on the types of farm animals.

Twenty seniors elected meat production and with the assistance of Mr. A. R. Potts were given as complete a course as the equipment at hand would allow. The abattoir is very small, and has no facilities for the handling of meats and keeping them any length of time. Until a suitable meat cutting room is arranged for and refrigeration provided for holding meat longer, it will not be possible for the students to get all that they should out of this course.

Very little change has been made in the herds and flocks the past year. It is hoped that the purchase of breeding females will no longer be necessary, new blood being added, by the purchase of high class sires from time to time. The beef herd has been added to by the purchase of a Shorthorn bull and the swine herd has been added to by the purchase of a Tamworth and a Duroc Jersey boar.

Existing conditions over which we have no control have prevented the carrying out of any experimental work during the past year, but we hope to be able to undertake some work in the near future.

Respectfully submitted,

GEO. A. BROWN,

Instructor in Animal Husbandry.

East Lansing, August 30, 1911.

REPORT OF THE DEPARTMENT OF FORESTRY.

To the President:

I herewith present my report as Professor of Forestry for the year ending June 30, 1911.

COURSE OF STUDY.

The course as set forth in the college catalogue for 1909-10 was followed with the exception of the summer term of the senior year.

The enrollment and comparison with other years, is as follows:

Term.	Year. 1908-09.	1909-10.	1910-11.
Summer	19	24	24
Fall	66	97	115
Winter	89	89	111
Spring	131	172	345
Total	302	382	595

Lectures were also given for four weeks to the Short Course students.

1911 SUMMER TERM.

The third session of the summer term, June 21st to August 10th is now being held on the estate of David Ward, Deward, Crawford county, Michigan. The field conditions are ideal. Camp is located adjacent to practical logging operations on a tract of virgin forest of 80,000 acres. Here it is possible to carry out the practical work which is so essential in the education of the forester.

The four courses as set forth in the 1910-11 college catalogue are being offered. Twenty-four students are in attendance.

It is recommended that next year's summer term be held for a period of eight weeks instead of seven as this year.

The department is keenly appreciative of the courtesy and kindness of Mr. W. C. Ward of Orchard Lake, Michigan, in permitting the use of the holdings of the estate as a field laboratory for forestry work.

The yearly field work in lumbering was not carried out as planned because of smallpox prevalent in the lumber camps during December.

FOREST EXTENSION WORK.

Owing to the lack of the services of a field man, properly qualified, in the department, no examinations of wood lots have been made. The teaching work has taken the entire time of the regular instructors. The inquiries from woodlot owners and others interested along forestry lines, have been more numerous than ever before. These inquiries have received the attention of the department.

A circular letter was issued during the early spring, offering the following tree stock at the prices quoted:

White pine seedlings, 2 years, 4 to 6 inches high, $2 per M.
White pine seedlings, 3 years, 6 to 9 inches high, $3 per M.
Norway pine transplants, 10 to 15 inches high, $10 per M.
Norway spruce transplants, 10 to 15 inches high, $10 per M.
White cedar transplants, 6 to 9 inches high, $10 per M.
Black locust seedlings, 1 to 2 feet high, $3 per M.
Black Walnut seedlings, 1 to 2 feet high, $5 per M.

Orders were received and shipments made as follows:

Orders received and shipments made.

Name.	Address.	Stock.
Henry B. Baker	R. No. 12, Box 69, Holland, Michigan	250 White Pine, 2yrs. 166 White Pine, 3 yrs. 140 Norway Spruce. 100 White Cedar. 200 Black Walnut. 200 Black Locust.
Dr. H. P. Baker	State College, Pa	500 Norway Pine. 500 Norway Spruce. 1,000 White Pine, 2 yrs.
J. S. Baker	St. Croix Falls, Wis	1,350 White Pine, 3 yrs.
Luther Baker	East Lansing, Mich	60 Red Cedar.
Dr. W. J. Beal	Amherst, Mass	25 Red Pines (small). 10 White Pine. 5 Yellow Pine (extra).
Bickell, Harry	Manistee, Mich	100 White Pine, 3 yrs. 25 Black Walnut. 30 Norway Spruce. 30 White Cedar.
Bickel, L. Louis	R. F. D. No. 3, Box 44, Vassar, Mich	300 Norway Spruce.
Bowen, Harvey	Sandusky, Michigan	3,000 White Pine, 3 yrs.
Cadwallader, E. M	Augusta, Mich	1,000 Norway Spruce.
Chittenden, A. W	Detroit, Mich	500 White Cedar.
Clark, Wm	Grand Rapids, Mich	1,000 White Pine, 2 yrs.
Cobb, M. A	Mt. Pleasant, Mich	500 Black Walnut.
Coon, W. M	Roscommon, Mich	100 Black Walnut.
Daines, Fred W	Farmington, Mich	1,000 Black Locust.
Diehm, Peter	Remus, Mich	1,000 Black Walnut.
Darbee, A. L	East Jordan, Mich	2,500 Norway Spruce.
Foster, S. A	Okemos, Mich	4,000 Black Locust.

Orders received and shipments made.—Continued.

Name.	Address.	Stock.
Frasier, J. O	Marlette, Mich	200 Black Walnut. 300 Black Locust. 100 Norway Spruce. 100 White Pine, 3 yrs.
Gargett, James B	Alma, Mich	200 Black Walnut.
Goehrend, A. C	Reed City, Mich	1,000 White Pine, 3 yrs.
Goold, C. S	Battle Creek, Mich	4,000 Black Locust.
Griffith, E. M	Madison, Wis	181,200 White Pine, 3 yrs. 5,000 Norway Spruce. 5,000 West. Yel. Pine. 1,000 Norway Pine.
Hamp, Geo	Jackson, Mich	1,000 Black Locust.
Hammer, H. T	Detroit, Mich	40 White Cedar. 30 Norway Pine. 30 Norway Spruce.
Hayden, I. J	Lowell, Mich	3,000 White Pine, 3 yrs.
Hedrick, W. O	East Lansing, Mich	100 Norway Spruce.
Hill, V. E	Plainwell, Mich	500 Black Locust. 100 White Cedar. 100 Norway Spruce.
Hilton, S. F	Grand Rapids, Mich	1,000 White Pine, 2 yrs.
Hoffman, Mrs. Max	St. Joseph, Mich	500 Norway Pine. 500 Norway Spruce.
Hoover, Joseph	Ionia, Mich	200 White Cedar.
Horton, Geo. B	Fruit Ridge, Mich	3,000 Black Walnut. 2,000 Black Walnut.
Judson, C. E	Lenawee Junction, Mich	1 Tulip. 1 Chestnut. 100 Black Walnut. 100 Black Locust.
Koch, Catherine	Kalamazoo, Mich	100 White Pine. 50 Black Locust. 50 Black Walnut. 10 Norway Pine. 10 Yellow Pine. 25 Norway Spruce. 5 White Cedar.

Orders received and shipments made.—Continued.

Name.	Address.	Stock.
Krentel, Andrew	East Lansing, Mich	60 Norway Spruce.
Krentel, Geo.	East Lansing, Mich	1 Ornamental Spruce.
Kruger, Wm	Lansing, Mich	2,000 Norway Spruce.
Lindemann, E. C.	East Lansing, Mich	3 Norway Spruce, 4 ft.
Mahrle, E.	Norvell, Mich	390 White Pine, 3 yrs. 50 Norway Pine. 50 Norway Spruce. 50 White Cedar.
Martin, John B	Grand Rapids, Mich	1,000 Norway Pine. 1,000 Norway Spruce. 1,000 White Cedar. 1,000 Black Locust. 1,000 Black Walnut.
Matheson, H. C.	South Frankfort, Mich	600 Norway Spruce.
Miller, John T	Birmingham, Mich	1,000 White Pine, 2 yrs.
Moll, Martin	Box 80, Fremont, Mich	200 Black Walnut.
Ohio Agricultural Exp. Station	Wooster, Ohio	25,000 White Pine, 2 yrs.
Piper, Wm. B., Forest Supervisor	Au Sable, Mich	3,000 White Pine. 5,000 White Pine, 2 yrs. 1,000 Norway Pine. 5,000 White Pine, 3 yrs.
Reynolds, W. W.	Cassopolis, Mich	2,000 Black Locust.
Ross, C. R	South Lyon, Mich	1,000 Black Locust.
Ruchs, E. W		50 Black Locust. 50 White Pine, 3 yrs. 50 Black Walnut.
Scovell, G. B	East Lansing, Mich	50 Norway Spruce.
Skeels, Dorr, Forest Supervisor	Libby, Montana	5,000 White Pine, 3 yrs.
Spross, Eli	Okemos, Mich	1,000 Black Locust.

Orders received and shipments made.—Concluded.

Name.	Address.	Stock.
True, Geo. A.	Armada, Mich.	1,000 White Pine, 3 yrs. 1,000 Black Locust. 1,000 Black Walnut.
Van Deman, John	Benzonia, Mich.	100 Norway Spruce.
Vasold, Hugo	Freeland, Mich.	200 White Cedar.
Vining, C. W.	Lakeview, Mich.	200 White Pine, 3 yrs. 500 Black Locust.
Wadsworth, Mrs. J.	Saranac, Mich.	300 White Pine, 3 yrs. 100 Norway Pine. 100 Norway Spruce. 100 White Cedar. 100 Black Locust.
Ward, Willis C.	Orchard Lake, Mich.	5,000 White Pine, 3 yrs. 100 Black Walnut. 100 Butternut. 100 West. Yellow Pine. 100 European Larch. 100 Norway Pine. 100 White Cedar. 100 White Ash. 100 Red Cedar.
Wheeler, Homer	Mt. Pleasant, Mich.	400 Black Locust.
Wheeler, W. J.	Mt. Pleasant, Mich.	1,000 Black Locust. 250 White Pine. 250 Black Walnut.
Wiegand, Frank J.	Detroit, Michigan.	1,200 Black Locust. 500 White Pine, 3 yrs. 2,000 Norway Spruce.
Wieland, Charles	R. No. 3, Lansing, Mich.	100 Black Walnut.
Wing, C. G.	Ludington, Mich.	1,000 Norway Spruce. 1,000 White Pine, 2 yrs. 1,000 Black Locust.
Wisner, Augusta B.	Clinton, Mich.	100 White Pine. 500 Norway Spruce. 100 Carolina Poplar.

Following trees were donated to Horticultural Department:
300 White pine, 3 years, 8 Basswood.
25 Red cedar, 35 Jack pine.
10 Jack pine, 22 Norway spruce.
6 Norway spruce, 200 Norway spruce.
2 Elm, 75 Red cedar.
Farm Department:
650 Norway spruce.

There is now on hand in the forest nursery, in nursery row and seed beds, 252,633 conifers and 40,630 broad-leaved forest trees of an especially large assortment of species at various stages of growth. This stock is in fine shape, of vigorous growth, the species being of such wide range that demands from any section of the state can be met with trees adapted to the soil conditions and the locality.

During the past year, 1,509 letters were sent out from this department.

Respectfully submitted,

J. FRED BAKER,
Professor of Forestry.

East Lansing, June 30, 1911.

REPORT OF DEPARTMENT OF AGRICULTURAL EDUCATION.

President J. L. Snyder:

Dear Sir:—I herewith submit a brief report of my labors during the year ending July 1st, 1911:

1. Teaching.—I have taught two classes in Pedagogics during the year covering seven and eight hours per week. One class consisted of juniors and seniors from the Home Economics course and the other of seniors from the Agricultural course. To the men I have presented special work in Agricultural Pedagogy preparatory to their teaching agriculture in public schools.

Nine men go out this year prepared from an academic standpoint, also having pedagogical training. Five new high schools will establish full courses in agriculture, beginning next September, located at South Haven, St. Johns, Traverse City, Mason and Adrian. In addition to these, some work in agriculture will be presented by under-graduates in the schools at Flushing, Addison and Farwell. Besides these schools taught by men from the college, some work in agriculture will be given by the science teachers in about one dozen other high schools. The total number of high schools giving regular courses in agriculture next year will be fourteen. The board of education at Hudson has discontinued the course in Agriculture. The work done in the ten high schools during the past year has been eminently practical and has convinced the people that the subject has a real place in the high school curriculum. At Watervliet ten farmers entered the class in live stock and dairying the first of December, and continued in daily attendance until the first of March. One of these farmers said to the superintend-

ent, "The value of this work in the high school is not fully appreciated. Just think of it, my son who will graduate next year will have a broader and better knowledge of the science of agriculture, than I have after thirty-five years of actual experience." This it seems to me is a fine testimonial.

The subjects taught in the high schools include agricultural botany, farm crops, horticulture, live stock and dairying, soil physics, breeding and feeding of live stock, farm management and farm mechanics.

2. Visitations.—During the year I have visited the ten high schools presenting agricultural subjects several times and have inspected carefully the conditions, laboratory facilities, practical work outside the school room and have kept in close touch with the work being done. In addition to this I have visited twenty-five high schools in regard to the establishment of courses in agriculture and several of these will introduce the course in 1912. I have also visited twenty schools with reference to their being placed upon our accredited list.

3. Extension Lectures.—During the winter months we conducted, in connection with each of the high schools, a series of schools or lectures for the farmers of the surrounding community. These schools were usually held on Saturday afternoon and were well attended. The instructor in agriculture had charge of the work and led at least half of the meetings and discussions; for the other half we provided members of the faculty of the college. In each case we consulted the farmers as to the line of work they desired to have presented. The subjects discussed included live stock improvement, soil fertility, grape culture, sheep husbandry, poultry, feeding, dairying, fertilizers, farm crops, and entomology.

4. Institutes.—I have given considerable time to farmers and teachers institutes. At the teachers institutes I have presented the means and methods of teaching elementary agriculture in the grades and in the rural schools. I also prepared and published a pamphlet for teachers on the subject of Rural Sociology and Elementary Agriculture. The institute I believe to be of great value and it is my opinion that the college should give more attention to the teachers in the public schools than has been done in the past. It offers a wide field for interesting the people in the college and in high schools. I have also assisted in the organization of the Association for Agricultural Education. The purpose of this organization is to promote the interest of agricultural education particularly in the secondary schools. Prof. K. L. Hatch of Wisconsin University is President and I have the honor at present to be Secretary of the organization. The first meeting was held in Chicago, April 10, 1911, and the next meeting will be held at the time of the National Association of Agricultural Colleges. During the year I have assisted in an investigation of rural, agricultural, and industrial education, in connection with the State Commission for that purpose. The report of this commission was submitted to the governor and to the last legislature in January, 1911.

5. Teachers.—The registration and location of teachers occupies a large amount of time and correspondence during the spring term. I have succeeded in locating ten men as teachers and up to the present time have located ten women, most of whom teach domestic science or art in the public schools of this state. I find that our women students

come into competition with graduates of normal schools and special schools in elementary courses in Domestic Science and Art, and it has required considerable time and energy to get a foot hold and get our graduates recognized by the superintendents of schools where such courses are presented. I feel sure that our young women will give a good account of themselves and if so this will assist us materially in the future and at the same time advertise our institution. I believe this to be an important field of work and that more time and attention should be given to it then we have been able to give up to the present time.

6. Extension Reading Course.—During the summer of 1910 we revised the circulars giving information in regard to our extension or correspondence reading course and sent out the circulars to all the granges and farmers' clubs of the state, as well as to a large number of individuals who had learned of its existence. The results have not been altogether satisfactory. During the fall of 1910 I gave fifty or more lectures to granges and other organizations, explaining the plan and urging the organization of reading clubs. As a result we have had clubs formed in twenty-five granges, five farmers clubs and two societies of Gleaners. We have had about 200 readers during the year and written reports are now being received from many of them. This is the third year of the course and we have kept about the same number of readers each year. The number has not increased as we had hoped it would. I am satisfied that if this work is to become of greater value, that more time and traveling must be given to it. I am not prepared to express an opinion as to the value of this work, or as to the advisability of continuing it indefinitely. I am hoping that by the end of another year we shall have arrived at more definite conclusions.

7. Employment Agency.—At the opening of the college year in the fall of 1910, a committee was appointed consisting of Prof. Kedzie and myself, which was to consider the advisability of establishing an employment agency through which we might assist students in securing work, and thus keep them in college. The committee arranged a plan of procedure and had suitable forms and report blanks prepared and employed Mr. R. E. Loree to take charge of the work. Mr. Loree had his headquarters in my office where he could be reached every evening from 6:30 to 8 o'clock.

Starting so late as we did, the plan was not well advertised or understood by the student body, and yet we believe the results have been good.

The following is a summary of the several reports made by Mr. Loree during the year:

a. Number of students enrolled during the year	193
b. Number of students employed	100
c. Number of students securing regular employment........	8
d. Total number of hours work	1,202

These students were employed for the most part off the grounds, though several of them had comparatively regular work on the grounds. The work done was of various kinds including pruning, piling brush, planting potatoes, spading, house cleaning, horticulture, typewriting, waiting table, fence building, gardening, picking fruit, raking leaves, dairy work, etc.

The figures given do not include the students regularly employed on the grounds or in the city. The farmers called for help, often more than we could find.

The students were paid from 15 to 20 cents an hour for their labor and so far as we are able to learn, the work was satisfactorily done and proved of great assistance to the students. I feel that this is a valuable movement and that if possible Mr. Loree should be employed to take charge of it for another year. He understands the work now and has an acquaintance which will enable him to handle it more effectively and with better satisfaction to all concerned.

Respectfully submitted,
WALTER H. FRENCH,
Professor of Agricultural Education.

East Lansing, June 30, 1911.

REPORT OF DEAN OF ENGINEERING.

Dr. J. L. Snyder, President, Michigan Agricultural College:

Dear Sir:—I present herewith my fourth annual report as Dean of Engineering.

The *personnel* of the several departments is given in the respective reports. There are thirty-one (31) teachers of all grades in the departments of the Division of Engineering. Inter-department relations have been pleasant and helpful. The organization designated as the Faculty of the Division of Engineering does not "fill a long felt want" owing to lack of authority or power in the administrative machinery of the college. The general faculty or the Board of Agriculture should assign to the division faculties definite authority in the administration of the included departments in order that these faculties may serve the purpose designated of giving to assistant professors and instructors a measure of interest and responsibility in the affairs of the departments and of the college.

The student enrollment in engineering was 481, a smaller number than last year, the shrinkage being in the sub-freshman year. There was a gain in enrollment in the four years above the sub-freshman.

The course of study has been revised, as in the other divisions, in accord with the instructions of the general faculty to reduce the credits to twenty (20) per week, the object being to give opportunity for better work by concentration in fewer subjects. The new course has been published in the catalog. Solid geometry has been made an entrance requirement for all courses and the sub-freshman course has been revised accordingly. The practice of giving professional technical work to sub-freshmen engineers has been discontinued.

The matter of salaries, which has been presented in previous reports is still a live and serious question. The writer is gratified over the merited advance granted to Professor Vedder and to Professor Polson and the small advances for other men and positions. The salary scale, however, is far below that recommended in my first annual report, which,

it seems to me should be attained before the salary schedule can be said to be on a satisfactory basis. It is particularly important, whatever may be the salaries offered, that appointees may be informed of the rate of advancement which will follow satisfactory service. A scale of salary increases would also reduce materially the duties of the President in connection with the annual task of appointments to the teaching staff.

I do hereby *again* recommend that the scale of salaries suggested in my first annual report be adopted as soon as practicable.

With the increased enrollment in professional engineering subjects it is important that teachers be specialists rather than interchangeable units in the administrative system.

This requirement will be impossible of attainment or satisfactory approximation at salaries now offered.

It is equally important that high grade teaching service be furnished in the general fundamental subjects, mathematics, English, etc., and this requirement is an additional reason for advanced salaries.

The increase in salary budget which would be entailed by adoption of the schedule suggested would be considerable but the maintenance of high teaching and administrative efficiency imperatively demand and justify the increase.

In conclusion I express my appreciation of the co-operation of authorities, colleagues and other co-workers in making the past year pleasant and profitable.

Respectfully submitted,
G. W. BISSELL,
Dean of Engineering.

East Lansing, June 30, 1911.

REPORT OF THE DEPARTMENT OF MECHANICAL ENGINEERING.

Dr. J. L. Snyder, President, Michigan Agricultural College:

Dear Sir:—I present herewith my report as Professor of Mechanical Engineering for the fiscal year ending June 30, 1911.

The opening of the college year witnessed several changes in the *personnel* of the department.

Assistant Professor, L. L. Appleyard, and Messrs. Hartman, Wilcox and Brackett had resigned to accept commercial positions. Mr. E. J. Kunze was appointed assistant professor in charge of machine design and shop work to succeed Mr. Appleyard, Mr. J. L. Morse was appointed instructor in machine design, Mr. E. A. Evans, foreman of the machine shop, and Mr. J. A. Neal, instructor in machine shop, these men succeeding Messrs. Hartman, Wilcox and Brackett, respectively.

The resignation of Prof. J. A. Polson was averted by a merited sub stantial advance in salary.

The new men have proven themselves to be exceptionally well qualified for their duties and I am pleased to note that present indications are that there will be no resignations from the staff.

The complete salaried *personnel* of the teaching force of the department is as follows:

G. W. Bissell, Professor of Mechanical Engineering.

J. A. Polson, Assistant Professor in charge of Engineering Laboratory.

E. J. Kunze, Assistant Professor in charge of Machine Design and Shop Work.

J. L. Morse, Instructor in Machine Design.

E. A. Evans, Foreman-instructor in Machine Shop.

A. P. Krentel, Foreman-instructor in Pattern Shop.

E. C. Baker, Instructor in Foundry.

W. R. Holmes, Instructor in Forge Shop.

A. Smith, Instructor in Pattern Shop.

J. A. Neal, Instructor in Machine Shop.

In addition to the above, Mr. G. W. Hobbs, '10, has been employed as laboratory assistant, and Messrs. Armstrong, Brightup, Coplan, and others as student assistants, as crowded sections have made necessary. Mr. E. C. Crawford has retained his connection as laboratory engineer and Miss C. B. Purcell as clerk.

The position held by Mr. Kunze should be advanced in salary and title. I recommend the creation of the position of Associate Professor in charge of machine design and practice with an initial salary of not less than $1,800.00 and a seat in the Faculty. Mr. J. A. Polson should be appointed Associate Professor in charge of experimental engineering and should have a seat in the Faculty.

There should be an additional salaried instructor whose duties should be chiefly in the engineering laboratory.

I am greatly pleased with the work of the department staff and the spirit of cooperation and loyalty shown.

The notable additions to the department equipment during the year have been a Kempsmith No. 2 universal milling machine and a Sullivan Machinery Co. two-stage steam air-compressor.

The machinery in the machine shop has been rearranged for greater convenience and efficiency.

The following graduating theses were done in the department during the year. The list does not include those done under the supervision of the other engineering departments:

Blust, J. A. Helm, L. C. Sauve, E. C.	Effect of Jacket Water Temperature upon Economy and Power Output of a Gasoline Engine.
Brightup, R. E. Thomas, C. P.	An Efficiency Comparison of a Scavenging Gasoline Motor.
Cleveland, O. H.	Comparative Tests on the Nordberg Corliss Engine.
DeKoning, J Perrin, S. W.	Heat Distribution on Elyria Gas Engine.
Edwards, R. C. Kolb, E. H.	Economy Test of Corliss Engine at High Pressure.
Hanish, C. C. Marsh, R. E.	Ventilation of Gladmer Theater.
Hookway, W.	Design of a Punching and Shearing Machine.
Jones, C. C. Tillotson, F. H.	Experimental Study of the Strength of Cast Iron Beams Involving a New Theory.

Lossing, H. A. Warmington, G.	Compression Tests on a Four-Stroke Cycle, Two Cylinder Tandem Gas Engine.
Osborn, G. H. Wallace, E. E	Heating and Ventilation of the First Baptist Church, Lansing, Mich.
Perham, S. H. Sanford, G. A.	Test on Fan, Engine and Stokers.
Russell, R. S. Smith, G. H.	Design of an Unloading and Distributing Covering System for the Coal Storage at M. A. C.
Wandel, E. P Schubach, E. G.	Study of Calibration of Three Venturi Tubes.

Below is given the schedule of class work for the year.

Respectfully submitted,

G. W. BISSELL,

Professor of Mechanical Engineering.

East Lansing, June 30, 1911.

Class-work of Department of Mechanical Engineering, Fall Term, 1910.

TABLE I.

Class.	Subject.	No. of course.	Teacher.	Hours per week each student.	No. of students enrolled.	Student hours per week.
Sub-freshmen	Wood-shop	2 m	Mr. Krentel Mr. Smith	4	42	168
4-year freshmen	Wood-shop	2 a	Mr. Krentel Mr. Smith	8	132	1,056
5-year freshmen	Wood-shop	2 p	Mr. Krentel Mr. Smith	4	43	172
Sophomores	Forge-shop	2 d	Mr. Holmes	8	61	488
Sophomores	Foundry	2 f	Mr. Baker	8	64	512
Juniors Seniors	Machine-shop	2 h 2 k	Mr. Evans Mr. Thompson	8	75	600
Juniors	Machine design	6 e	Mr. Morse	6	41	246
Juniors	Metallurgy	11	Prof. Polson Prof. Kunze	2	77	154
Seniors	Steam engine design	8 b	Prof. Kunze	6	22	132
Seniors	Engineering laboratory	13 c	Prof. Polson Mr. Hobbs	8	57	456
Seniors	Heating and Ventilation	18 a	Prof. Bissell	3	49	147
Totals					663	1,431

Class-work of Department of Mechanical Engineering, Winter Term, 1911.

TABLE II.

Class.	Subject.	No. of course.	Teacher.	Hours per week each student.	No. of students enrolled.	Student hours per week.
Sub-freshmen	Wood-shop	2 n	Mr. Krentel, Mr. Smith	4	38	152
4-year freshmen	Wood-shop	2 b	Mr. Krentel, Mr. Smith	8	115	920
5-year freshmen	Wood-shop	2 q	Mr. Krentel, Mr. Smith	4	36	144
4-year and 5-year freshmen	Elements of Engineering	1	Prof. Bissell	2	147	294
Sophomores	Forge Shop	2 e	Mr. Holmes	8	63	504
Sophomores		2 g	Mr. Baker	8	52	416
Sophomores	Empirical design	6 a	Prof. Kunze, Mr. Morse, Student assts	6	113	678
Juniors, Seniors	Machine-shop	2 i, 2 l	Mr. Evans, Mr. Neal	8	83	664
Juniors	Steam & Gas Engineering	7 a	Prof. Kunze, Mr. Morse	5	71	355
Juniors	Machine design	6 d	Mr. Morse	6	37	222
Juniors	Engineering laboratory	13 a	Prof. Polson, Mr. Hobbs	4	66	264
Seniors	Engineering laboratory	13 d	Prof. Polson, Mr. Hobbs	8	21	168
Seniors	Works. Management	5 a	Prof. Kunze	3	20	60
Seniors	Machine, Tool & Jig design	6 e	Prof. Kunze	8	23	184
Seniors	Power station design	18 b	Prof. Bissell	5	20	100
Totals					905	5,125

Class-work of Department of Mechanical Engineering, Spring Term, 1911.

TABLE III.

Class.	Subject.	No. of course.	Teacher.	Hours per week each student.	No. of students enrolled.	Student hours per week.
Sub-freshmen	Wood-shop	2 o	Mr. Krentel Mr. Smith	4	29	116
4-year freshmen	Wood-shop	2 c	Mr. Krentel Mr. Smith	6	102	612
5-year freshmen	Wood-shop	2 r	Mr. Krentel Mr. Smith	4	30	120
Sophomores	Forge-shop	2 e	Mr. Holmes	8	44	352
Sophomores	Foundry	2 g	Mr. Baker	8	55	440
Sophmores	Kinematics	6 b	Prof. Kunze Mr. Morse Student assts	4	102	408
Juniors	Machine-shop	2 j	Mr. Evans Mr. Neal	8	70	560
Juniors	Thermodynamics	17 a	Prof. Bissell Prof. Polson Prof. Kunze	3	62	186
Juniors	Engineering laboratory	13 b	Prof. Polson Mr. Hobbs	4	56	224
Juniors	Kinematics	14 a	Prof. Kunze Mr. Morse	2	66	132
Juniors	Steam engine	8 a	Mr. Morse	4	33	132
Seniors	Gas power engineering	8 c	Prof. Kunze	3	30	90
Seniors	Machine tool design	6 f	Prof. Kunze	6	9	54
Seniors	Costs, accounting, etc	18 c	Prof. Bissell	2	53	106
Seniors	History of engineering	18 d	Prof. Bissell	2	48	96
Seniors	Thesis	19 a	Prof. Bissell Prof. Polson Prof. Kunze	20	20	400
Totals					809	4,028

REPORT OF THE DEPARTMENT OF CIVIL ENGINEERING.

President J. L. Snyder:

Dear Sir:—It is a pleasure to hand you the record of a year so generally filled with efficiency and satisfaction. Many elements have conspired to these gratifying conditions, chief among which are harmony and hard work on the part of the departmental staff, aided by a receptive, purposeful attitude of the students we have met in the field-work, classes and laboratories. I wish to heartily and emphatically commend the work of all the teachers of civil engineering, who, without exception, have labored industriously to make this a successful year.

At the beginning of the fall term the departmental staff consisted of the following teachers, whose names are given in order of seniority of appointment:

H. K. Vedder, C. E., Professor of Civil Engineering.

W. B. Wendt, B. C. E., Assistant Professor of Civil Engineering.

A. S. Rosing, B. S. in C. E., Assistant Professor of Civil Engineering.

J. T. Buser, B. S. in C. E., Instructor in Civil Engineering.

H. E. Marsh, B. S., Instructor in Civil Engineering.

A. M. Ockerblad, B. S. in C. E., Instructor in Civil Engineering.

As for several years past our spring term teaching schedule imposed requirements beyond the physical capacity of the regular staff. Accordingly, two additional instructors were engaged to assist during the months of April, May and June. These appointees were Mr. B. K. Philp, C. E., and Mr. James E. Shaw, B. S.

Of the regular teaching staff named above Prof. Rosing and Mr. Buser have resigned and will take up work elsewhere. Satisfactory candidates to supply these vacancies are being sought for and the Board has authorized the engagement of an additional instructor. It is very difficult to secure competent teachers at the salaries offered and more difficult to retain them long.

Of the one hundred twenty-eight young men and women who were graduated from the college a few weeks ago, and who received the bachelor's degree, thirty-one were those who had specialized in civil engineering. The class as a whole was the largest in the history of the institution. I may be pardoned for noting that the civil engineers comprise a larger group of the class than can be claimed by any other department of the institution if there is recognized a differentiation or specialization in agriculture and horticulture.

The election of civil engineering studies by our engineer students has been large for some years and is increasing until it seems to me to constitute an abnormal condition which will no doubt in time adjust itself. However, the expressed intuitions of those who have just become juniors indicate no immediate change and our facilities of all kinds for the purposes of instruction will be taxed to the utmost throughout the coming year.

I contemplate with some misgivings the possibilities of injury and deterioration which must come to our instrumental equipment, if it

can not be more regularly inspected and carefully kept than in the past. We have a remarkably complete outfit of instruments of the best class for field work, about as numerous as can conveniently be stored and handled in the space available for the purpose. The maximum economy of service with this equipment requires its use by different groups of students in the same week, often on the same days of the week, and under the supervision of different instructors. The requirements of our teaching schedule often make it impossible for the instructor to examine instruments that have been returned by his class after use in the field, until the same tools have been used by others. Naturally there results a divided responsibility which is not conducive to the integrity of the instruments. The remedy for such a situation lies in the appointment of an assistant whose most important duty shall be the constant care and inspection of all surveying instruments, field tools and some of our laboratory equipment. Cleaning and repairs could be placed in his charge. Breakage and injury could be determined at the proper time and assessments could be levied accordingly upon the proper persons.

As for many years past, I present herewith a tabulation showing the work of teaching carried out by this department during the year; it will answer questions of assignments, enrollment, classrooms occupied, size of sections and the like.

Class work of the department of Civil Engineering for the college year 1910-1911.

Class.	Subject.	No. of course.	Teacher.	Classroom.	Hour of meeting.	No. hours per week.	No. of students in class.
Fall term.							
Juniors.....	Mech. of Eng...........	C.E. 4a.	Prof. Rosing............	203 Eng. Bldg....	8-9	5	17
Juniors.....	Mech. of Eng...........	C.E. 4a.	Mr. Buser..............	302 Eng. Bldg.....	8-9	5	21
Juniors.....	Mech. of Eng...........	C.E. 4a.	Mr. Marsh..............	203 Eng. Bldg....	1-2	5	14
Juniors.....	Mech. of Eng...........	C.E. 4a.	Mr. Ockerblad..........	302 Eng. Bldg....	1-2	5	14
Juniors.....	Adv. Surveying (class)...	C.E. 6..	Mr. Buser..............	203 Eng. Bldg....	9-10	3	20
Juniors.....	Adv. Surveying (field)...	C.E. 6..	Mr. Buser, Mr. Marsh....	203 Eng. Bldg....	1-3	4	20
Juniors.....	Adv. Surveying (class)...	C.E. 6..	Mr. Buser..............	302 Eng. Bldg....	3-4	3	15
Juniors.....	Adv. Surveying (field)....	C.E. 6..	Mr. Buser, Mr. Ockerblad.	306 Eng. Bldg....	10-12	4	15
Juniors.....	Adv. Surveying (class)...	C.E. 6..	Mr. Marsh..............	203 Eng. Bldg....	3-4	3	18
Juniors.....	Adv. Surveying (class)...	C.E. 6..	Mr. Ockerblad..........	302 Eng. Bldg....	9-10	3	22
Juniors.....	Adv. Surveying (field)....	C.E. 6..	Mr. Ockerblad..........	306 Eng. Bldg.....	2-4	4	22
J'rs & S'rs..	Surveying methods (class)	C.E. 2..	Prof. Wendt............	109-111 Eng. Bldg.	8-9	3	30
Seniors.....	Surveying methods (field)	C.E. 2..	Prof. Wendt............	....	8-10	4	30
Seniors.....	Graphic Statics..........	C.E. 4d.	Mr. Marsh..............	401 Eng. Bldg....	8-9	3	29
Seniors.....	Graphic Statics..........	C.E. 4d.	Mr. Marsh..............	401 Eng. Bldg....	9-10	3	28
Seniors.....	Hydraulics.............	C.E. 5..	Prof. Rosing............	203 Eng. Bldg....	10-11	5	32
Seniors.....	Hydraulics.............	C.E. 5..	Prof. Wendt............	203 Eng. Bldg....	11-12	5	23
Seniors.....	Hydraulic Lab.	C.E. 5a.	Prof. Rosing............	3-106 Eng. Bldg...	1-4	6	20
Seniors.....	Hydraulic Lab..........	C.E. 5a.	Prof. Wendt............	3-106 Eng. Bldg...	1-4	6	16
Seniors.....	Adv. Surveying (class)...	C.E. 6b.	Prof. Vedder............	111 Eng. Bldg....	8-9	2	17
Seniors.....	Adv. Surveying (class)...	C.E. 6b.	Prof. Vedder............	111 Eng. Bldg....	9-10	2	19
Seniors.....	Adv. Surveying (field)....	C.E. 6b.	Prof. Vedder, Mr. Buser..	304 Eng. Bldg....	1-5	4	17
Seniors.....	Adv. Surveying (field)....	C.E. 6b.	Prof. Vedder, Mr. Ockerblad.......	111 Eng. Bldg....	8-12	4	19
Seniors.....	Bridge Stresses..........	C.E. 8a.	Prof. Vedder............	111 Eng. Bldg....	10-11	3	16
Seniors.....	Bridge Stresses..........	C.E. 8a.	Prof. Vedder............	111 Eng. Bldg....	11-12	3	19
Totals..	25 sections............	....	....	....	....	97	513

Class.	Subject.	No. of course.	Teacher.	Classroom.	Hour of meeting.	No. hours per week.	No. of students in class.
Winter term.							
Juniors.....	Mechanics..............	C.E. 4b.	Mr. Buser..............	302 Eng. Bldg....	8–9	5	16
Juniors.....	Mechanics..............	C.E. 4b.	Mr. Buser..............	302 Eng. Bldg....	1–2	5	16
Juniors.....	Mechanics..............	C.E. 4b.	Mr. Ockerblad..........	401 Eng. Bldg....	8–9	5	15
Juniors.....	Mechanics..............	C.E. 4b.	Mr. Ockerblad..........	401 Eng. Bldg....	1–2	5	19
J'rs, S'rs....	Agr. Eng...............	C.E. 3..	Prof. Vedder...........	111 Eng. Bldg....	9–10	5	48
Seniors.....	Hydraulic Motors........	C.E. 5b.	Prof. Wendt............	203 Eng. Bldg.....	1–2	3	27
Seniors.....	Hydraulic Motors........	C.E. 5b.	Prof. Rosing............	111 Eng. Bldg....	1–2	3	24
Seniors.....	Bridge Design...........	C.E. 8b.	Prof. Vedder, Mr. Marsh..	304-306 Eng. Bldg.	10–12	8	34
Seniors.....	Mas'y and arches (class)..	C.E. 9..	Mr. Marsh..............	111 Eng. Bldg....	8–9	3	17
Seniors.....	Mas'y and arches (draw'g)	C.E. 9..	Mr. Marsh..............	306 Eng. Bldg....	10-12 2–4	4	17
Seniors.....	Mas'y and arches (class)..	C.E. 9..	Prof. Wendt............	203 Eng. Bldg....	8–9	3	16
Seniors.....	Mas'y and arches (draw'g)	C.E. 9..	Prof. Wendt............	304 Eng. Bldg....	10-12 2–4	4	16
Seniors.....	Roads and pavements....	C.E. 10.	Prof. Rosing............	111 Eng. Bldg....	8–9	2	36
Seniors.....	Experimental Lab.......	C.E. 12.	Prof. Wendt, Mr. Buser..	106–4 Eng. Bldg...	8–12 2–5	8	18
Seniors.....	Experimental Lab.......	C.E. 12.	Prof. Rosing, ... Mr. Ockerblad.......	106–4 Eng. Bldg...	8–12 2–5	8	17
Seniors.....	Water supply, sewerage..	C.E. 15.	Prof. Rosing............	203 Eng. Bldg....	9–10	5	33
Totals..	16 sections............	....	....	....	....	76	369

Class.	Subject.	No. of course.	Teacher.	Classroom.	Hour of meeting.	No. hours per week.	No. of students in class.
Spring term.							
Sophomores.	Surveying (class)	C.E. 1a.	Mr. Shaw	401 Eng. Bldg	1–2	2	28
Sophomores.	Surveying (field)	C.E. 1a.	Mr. Shaw, Mr. Philp		10–12	2	62
Sophomores.	Surveying (class)	C.E. 1a.	Mr. Shaw	203 Eng. Bldg	8–9	2	34
Sophomores.	Surveying (field)	C.E. 1a.	Mr. Shaw, Mr. Philp		1–3	2	63
Sophomores.	Surveying (class)	C.E. 1a.	Mr. Philp	111 Eng. Bldg	1–2	2	29
Sophomores.	Surveying (class)	C.E. 1a.	Mr. Philp	111 Eng. Bldg	8–9	2	34
Sophomores.	Surveying (class)	C.E. 1a.	Mr. Buser	302 Eng. Bldg	11–12	2	26
Sophomores.	Surveying (field)	C.E. 1a.	Mr. Buser, Mr. Philp	203 Eng. Bldg	8–10	4	26
Sophomores.	Surveying (class)	C.E. 1a.	Mr. Buser	302 Eng. Bldg	2–3	2	29
Sophomores.	Surveying (field)	C.E. 1a.	Mr. Buser, Mr. Philp	302 Eng. Bldg	3–5	4	31
Sophomores.	Surveying (class)	C.E. 1a.	Mr. Ockerblad	302 Eng. Bldg	11–12	2	25
Sophomores.	Surveying (field)	C.E. 1a.	Mr. Ockerblad, Mr. Shaw		8–10	4	23
Sophomores.	Surveying (class)	C.E. 1a.	Mr. Ockerblad	302 Eng. Bldg	2–3	2	30
Sophomores.	Surveying (field)	C.E. 1a.	Mr. Ockerblad		3–5	4	32
Juniors	Topog. Sur'g (class)	C.E. 2a.	Prof. Wendt	111-203 Eng. Bldg.	2–3	2	16
Juniors	Topog. Sur'g (field)	C.E. 2a.	Prof. Wendt		3–5	6	16
Juniors	Str. of materials	C.E. 4c.	Prof. Wendt	203 Eng. Bldg	9–10	5	15
Juniors	Str. of materials	C.E. 4c.	Prof. Wendt	203 Eng. Bldg	1–2	5	15
Juniors	Str. of materials	C.E. 4c.	Mr. Marsh	111 Eng. Bldg	8–9	5	17
Juniors	Str. of materials	C.E. 4c.	Mr. Marsh	302 Eng. Bldg	1–2	5	13
Juniors	Topog. mapping (lab)	C.E. 6a.	Mr. Marsh		10–12	4	15
Juniors	Topog. mapping	C.E. 6a.	Mr. Mrash		3–5	4	20
Juniors	Topog. mapping	C.E. 6a.	Mr. Marsh, Mr. Shaw		10–12	4	15
Juniors	Topog. mapping	C.E. 6a.	Mr. Marsh, Mr. Shaw		3–5	4	20
Juniors	R. R. surveying (class)	C.E. 7.	Prof. Rosing	111 Eng. Bldg	8–9	3	17
Juniors	R. R. surveying (field)	C.E. 7.	Prof. Rosing, Mr. Buser	401–106 Eng. Bldg	1–5	4	17
Juniors	R. R. surveying (class)	C.E. 7.	Prof. Rosing	111 Eng. Bldg	2–3	3	18
Juniors	R. R. surveying (field)	C.E. 7.	Prof. Rosing, Mr. Buser	401-106 Eng. Bldg.	8–12	4	18
Juniors	Road construction (class)	C.E. 17.	Prof. Rosing	109 Eng. Bldg	11–12	2	15
Juniors	Road construction (field)	C.E. 17.	Prof. Rosing, Mr. Ockerblad	401 Eng. Bldg	10–12	6	15
Seniors	Thesis	C.E. 11.	Prof. Vedder	106 Eng. Bldg	1–5	10	30
Seniors	Contracts and Specif	C.E. 13.	Prof. Vedder	111 Eng. Bldg	10–11	3	28
Seniors	Contracts and Specif	C.E. 13.	Prof. Vedder	111 Eng. Bldg	11–12	3	25
Seniors	Astronomy (class)	C.E. 14.	Prof. Vedder	111 Eng. Bldg	11–12	2	31
Seniors	Astronomy (field)	C.E. 14.	Prof. Vedder	111 Eng. Bldg		2	31
Totals.	35 sections					122	879

The following text books have been used in our classes during the year: Merriman and Jacoby's Roofs and Bridges, Vols. I, II, III; Hodgman's Land Surveying and Vedder's Notes on Surveying; Church's Mechanics; Baker's Masonry Construction; Baker's Roads and Pavements; Merriman's Treatise on Hydraulics; Turneaure & Russell's Public Water Supplies; Folwell's Sewerage; Wilson's Topographic Surveying; Tucker's Contracts in Engineering; Hosmer's Astronomy; Merriman's Mechanics of Materials; Godwin's Railroad Engineers' Field Book; Johnson—Smith's Surveying.

The total expenditure by the department during the year for all purposes has been $2,510.95 of which $78.00 was turned in for special examinations, and $659.00 for laboratory fees and other departmental receipts.

Respectfully submitted,
H. K. VEDDER,
Professor Civil Engineering.

East Lansing, Mich., June 30, 1911.

REPORT OF THE DEPARTMENT OF PHYSICS AND ELECTRICAL ENGINEERING.

President J. L. Snyder:

Dear Sir:—The past year, 1910-1911, has been very much like the preceding one. We had very much the same instructional force and accomplished about the same amount of work.

During this school year the faculty have changed the required work so that twenty credits per term will be required after this year instead of twenty-five as heretofore. This of course necessitated rearranging the work and, together with the changes in the home economics course, some difficulty was experienced in making it possible for every student to get the amount of physics that his course called for. For that reason in the spring term we had to forego laboratory work in the home economics and agricultural courses.

It is difficult, with the changes that are being made, to keep the amount of work done in the three terms uniform, so that the staff may be equally busy each term. For example, our fall term has for several years been the light term. The winter term has been heavier, and the spring term so heavy that the staff were hardly able to carry all the work. I have tried in the reorganization of the courses this year to even it up but I think that our spring term will still be the heaviest term of the year.

Not many additions to our laboratory equipment have been made during the year, but a few very much needed ones have been provided.

For three years now the department has held an "electrical show" near the latter part of the winter term and it seems to be justified from the interest shown and the questions asked. Electricity is entering every phase of life,—the home, the factory and the farm, to such an extent that it is essential that every one should have an intelligent knowledge of its uses. The electrical show seems to accomplish this purpose. We also take occasion, at the time of the Round-Up Institute occurring about the same time, to have the various uses of electricity on exhibition for the benefit of those attending. All this is accomplished with a very slight expense to the department and I hope in another year to be able to accomplish more, although our space that can be assigned to such exhibition work is becoming less every year.

Mr. H. E. Marsh, who was with the department during 1909 and 1910, has been with the civil engineering department this year.

Mr. Oren L. Snow, a graduate of the class of 1910, has been instructor in the preparatory work in physics. Mr. Snow has proven a very useful and intelligent instructor. He evidently was cut out to be a teacher.

Mr. Ernest Roller, who has been with us two years, resigned in order to give his attention to commercial matters. His connection with the department has been very pleasant indeed. Those who have become acquainted with Mr. Roller and his family have had a concrete example of how a family can come and enter into the life of a community and be very helpful and useful even though they do stay but two years.

Most families take two years to get started. Mr. Roller and family seemed to start in the first month they came. Their presence in the community will be missed considerably.

Mr. C. W. Chapman, who was with us during the years 1907, 1908 and 1909, has been reengaged after a period spent in study at the University of Michigan and the University of Chicago, and we are looking forward to a pleasant and profitable year with an entire complement of teachers who have been with us before. Breaking in a new instructor interferes very seriously with the work of the department.

I wish here to record appreciation of the staff in the department, as listed below, for their interest and efficiency.

Assistant Professor: W. L. Lodge.

Instructors: W. E. Laycock, G. A. Kelsall, E. Roller, O. L. Snow.

Clerk and Stenographer one-fourth time: Miss Edna B. Spindler.

Caretaker: George Klotz.

Below is a table showing the work carried by this department during the year.

Class.	Subject.	Instructor.	Section for lectures.	Hours for lectures.	Section for recitations.	Hours for recitations.	Section for laboratory.	Hours for laboratory.	Number of students.
Spring term.									
Sub-freshmen	Physics 1b	Mr. Snow	1	1	4	12	1	2	53
Sub-freshmen	Physics 1b	Mr. Laycock					2	4	32
Sub-freshmen	Physics 1b	Mr. Roller					1	2	12
Sub-freshmen	Physics 2c	Mr. Snow	1	1	2	4	2	4	27
Sub-freshmen	Physics 2c	Mr. Roller					1	2	16
Sub-freshmen	Physics 3b	Mr. Laycock	1	1	1	3	2	4	24
Freshmen	Physics 1d	Mr. Roller	2	2	6	12			128
Freshmen	Physics 3d	Mr. Laycock	1	1	4	8			98
Sophomores	Physics 2f	Prof. Lodge	2	4	4	8	4	8	113
Sophomores	Physics 2f	Mr. Kelsall					4	8	51
Juniors	E. E. 1c	Prof. Sawyer			2	6			30
Juniors	E. E. 1c	Mr. Kelsall					3	12	31
Seniors	E. E. 7	Prof. Sawyer	Thesis	Time as	required.				3
Seniors	E. E. 8	Prof. Sawyer					1	6	4
Seniors	E. E.	Prof. Sawyer			1	2			7
Seniors	Physics 4c	Prof. Sawyer			1	2	1	2	8

Class.	Subject.	Instructor.	Section for lectures.	Hours for lectures.	Sections for recitations.	Hours for recitations.	Sections for laboratory.	Hours for laboratory.	Number of students.
Winter term.									
Sub-freshmen	Physics 3a	Mr Laycock	1	1	1	3	2	4	28
Sub-freshmen	Physics 1a.	Mr. Laycock	1	1	4	12	1	2	16
Short course	Physics	Mr. Laycock	1	1					43
Sub-freshmen	Physics 1a	Mr. Snow					3	6	43
Sub-freshmen	Phy's 1a, 2b	Mr. Carpenter.					1	2	15
Sub-freshmen	Physics 2b	Mr. Snow	1	1	2	2	2	4	39
Sophomores	Physics 2e	Prof. Lodge	2	4	4	8	4	8	121
Sophomores	Physics 2e	Mr. Snow					4	8	57
Sophomores	Physics 1f	Mr. Roller	1	2	4	8	6	12	104
Short course	Physics	Mr. Roller	1	2					43
Juniors	E. E. 1b	Prof. Sawyer			2	6			36
Juniors	E. E. 1b	Mr. Kelsall					2	4	36
Juniors	E. E. 6a	Mr. Kelsall			2	4	2	8	29
Seniors	E. E. 3b	Prof. Sawyer			1	5			8
Seniors	E. E. 3b	Mr. Kelsall					1	4	8

Class.	Subject.	Instructor.	Sections for laboratory.	Hours for lectures.	Sections for recitations.	Hours for recitations.	Sections for laboratory.	Hours for laboratory.	Number of students.
Fall term.									
Sub-freshmen..	Physics 2a..	Mr. Snow.....	1	1	2	4	....	....	45
Sophomores....	Physics 2d..	Prof. Lodge...	2	4	4	8	4	8	134
Sophomores....	Physics 2d..	Mr. Snow.....	....	....	....	....	4	8	95
Sophomores....	Physics 1c..	Mr. Roller....	1	2	4	8	6	12	111
Sophomores....	Physics 1c..	Mr. Laycock..	....	....	....	....	1	2	16
Sophomores....	Physics 3c..	Mr. Laycock..	1	1	2	4	3	12	71
Juniors........	E. E. 1a....	Prof. Sawyer..	2	2	....	....	2	8	39
Juniors........	E. E. 4a....	Mr. Kelsall...	....	....	....	....	2	4	37
Juniors........	E. E. 6a....	Mr. Kelsall....	1	1	2	6	....	....	54
Seniors........	E. E. 3a....	Prof. Sawyer..	....	....	2	6	....	....	24

Respectfully,

A. R. SAWYER,

Professor of Physics and Electrical Engineering.

East Lansing, Mich., June 30th, 1911.

REPORT OF THE DRAWING DEPARTMENT.

President J. L. Snyder:

Dear Sir:—I herewith beg leave to submit to you my annual report as head of the Department of Drawing and Design for the year ending June 30th, 1911.

The work of the department has progressed very satisfactorily, if anything, with better results in the teaching all along the line. Considerable interest was manifested by the women students in their freehand drawing studies and many inquiries were made by them in regard to electing if possible more work along the same lines.

I may remind you in my last annual report I recommended the establishment of an industrial arts course for the women, so that they may have more options and an opportunity for technical training commensurate with the opportunities open to the men. The indications point very strongly to a demand for this kind of work. I wish to add to what I have formerly said upon this subject that I believe the opening of greater opportunities for the women would not necessarily attract more women to our doors so much as it would a better quality of students, and indirectly contribute to the settlement of other administrative problems.

In the spring we arranged with the firm of Atkinson, Mentzer & Grover of New York to send us an exhibit of arts and crafts work. It came and proved to be the exclusive work of the School of Industrial Art at Philadelphia, Pa. During its few days' stay it enlisted a great deal of interest both from students and faculty and emphasized the view I have expressed that such work should be available for the women.

Again I am inclined to be strong in my praises of the esprit de corps of the teaching staff who have done all they could to make the department work successful and I may add that we are fortunate in getting such good work from them when commercial positions at higher salaries invite

them elsewhere. I have spoken previously upon the need of higher salaries for the teaching staff. In considering plans for next year I have found that our available salaries are not strong inducements to prospective teachers. A number of good candidates have completely turned our propositions down and I do not think I am presenting this matter to strongly when I make this statement to you and also express my belief that we are likely to experience future insurmountable difficulties in obtaining teachers if the salary scale is not increased. I believe also that there should by all means be established a scale of salary increase to which deserving instructors could look forward from year to year. I lose a very valuable man, Mr. C. P. Thomas, at the close of this college year who gives up his position because the salary increase was not what he thought he deserved and I may admit I quietly agreed with him.

The department teaching has been done with the assistance of the following staff mentioned in the order of seniority of appointment:

Chace Newman, Assistant Professor of Drawing.
Miss Caroline Holt, Instructor in Drawing.
Miss Isabel Snelgrove, Instructor in Drawing.
Bertram P. Thomas, Instructor in Drawing.
Max D. Farmer, Instructor in Drawing.
Miss Bessie Bartholomew, Assistant Instructor in Drawing.
Leo J. Knapp, Student Assistant in Drawing.

Again this year, owing to the irregularity of the schedule, we were required to get the assistance of Miss Bartholomew for teaching the freehand drawing classes and as before she gave very satisfactory service. Mr. L. J. Knapp for similar reasons was employed as student assistant in the drawing classes in descriptive geometry and did very good work.

The revision of courses in the college on the twenty credit basis which was so much needed has resulted in a heavy draft in the spring term and will cause an equally unbalanced schedule next year until things are evened up.

A new system has been adopted by us the present year to increase the efficiency of teaching mechanical drawing, namely the use of printed layouts to save students time in laying out fundamental data of problems. It has fulfilled all expectations and is strongly endorsed by the students as well as the teachers. It is an idea that has originated in this department and it seems to indicate a very advanced step in the teaching of graphical subjects. Mr. Newman and I have been at work upon the system for more than a year.

We have not made any noticeable additions to our equipment, not because it was not needed, but because other department administrative work seemed to take up our time and it was temporarily set aside.

Following is a table which will show much data regarding attendance, teaching hours, etc.:

Drawing department.

Class.	Subject.	Instructor.	Fall term.		Winter term.		Spring term.	
			Hours per week.	No. of students	Hours per week.	No. of students.	Hours per week.	No. of students.
Sub-freshman—Ags	Drawing 1	Miss Holt	2	23				
		Miss Snelgrove	2	32				
Sub-freshman—Ags	Drawing 1a	Prof. Wilson			4	14		
		Miss Snelgrove			2	28		
		Miss Snelgrove			2	32		
Sub-freshman—Engineers	Drawing 4ac	Mr. Thomas	6	21				
		Mr. Thomas	6	21				
Sub-freshman—Engineers	Drawing 4d	Mr. Farmer			6	14		
		Mr. Thomas			6	21		
Sub-freshman—Engineers	Drawing 4f	Prof. Wilson					4	28
Freshman—Ags	Drawing 1c	Miss Holt	4	13				
		Miss Holt	4	23				
		Miss Snelgrove	4	22				
		Miss Snelgrove	4	24				
		Miss Bartholomew	4	19				
		Miss Bartholomew	4	14				
		Miss Bartholomew	4	19				
		Miss Bartholomew	4	18				
Freshman—Engineers	Drawing 4ab	Prof. Newman	6	33				
		Mr. Farmer	6	31				
		Mr. Thomas	6	31				
		Mr. Thomas	6	33				
	Drawing 4e	Prof. Newman			8	26		
		Mr. Farmer			8	27		
		Mr. Thomas			8	32		
		Mr. Thomas			8	26		
	Drawing 5ab	Prof. Wilson					3	30
		Prof. Wilson					6	24
		Prof. Newman					6	27
		Prof. Newman					3	29
		Prof. Newman					3	13
		Mr. Farmer					3	23
		Mr. Farmer					6	26
		Mr. Thomas					3	20
		Mr. Thomas					6	24
		Mr. Thomas					3	29
		Mr. Thomas					6	23
		Mr. Knapp					6	23
Freshman—H. E.	Drawing 1b	Prof. Wilson	6	21				
		Miss Holt	6	23				
		Miss Snelgrove	6	24				
		Miss Snelgrove	6	24				
	Drawing 1d	Prof. Wilson			4	21		
		Miss Holt			4	20		
		Miss Snelgrove			4	22		
		Miss Snelgrove			4	24		
Sophomore—Ags	Drawing 3b	Prof. Newman					6	28
		Miss Snelgrove					6	39
		Miss Snelgrove					6	24
		Miss Snelgrove					6	21
Sophomore—Engineers	Drawing 5b	Prof. Wilson	5	29				
		Prof. Newman	5	33				
		Prof. Newman	5	32				
		Mr. Farmer	5	31				
Sophomore—H. E.	Drawing 2a	Miss Holt					3	24
		Miss Holt					5	26
		Miss Snelgrove					2	24
		Miss Holt					4	25
		Miss Holt					4	14
Junior & Senior—Ags	Drawing 3c	Mr. Farmer					7	10
Junior—Engineers	Drawing 6	Mr. Farmer	6	19				
		Mr. Farmer	6	19				
	Drawing 7	Prof. Newman			6	18		
		Mr. Farmer			6	20		
Junior—H. E.	Drawing 1e	Miss Holt	4	7				
Junior & Senior—H. E.	Drawing 2b	Miss Holt			5	36		
	Drawing 1c	Miss Holt					4	8

Very respectfully submitted,

VICTOR T. WILSON,

Professor of Drawing and Design.

East Lansing, Mich., June 30th, 1911.

REPORT OF THE DEAN OF HOME ECONOMICS.

To the President:

Permit me to submit my report as Dean of Home Economics for the year 1910-11.

The Home Economic Division enrolled during the year 236 students, of whom 25 were graduated in June. Howard Terrace was used again for the overflow of new students and for additional piano rooms, proving a satisfactory building for this purpose. An epidemic of measles and mumps continuing in spite of all precautions through the winter and into the spring, gave us reason to wish for the freedom of our convalescents' room, instead of using it for regular students. Miss Agnes Hunt, an alumna of the University of Illinois and director of Domestic Science in the government school, the College of Hawaii, began her duties as professor of Domestic Science in September. With the assistance of Miss Grace E. Stevens, also a graduate of the University of Illinois, she has instituted important changes in the work and equipment of the department. During the present summer the laboratory is being remodelled with the aim of carrying on more scientific work in dietetics and food values than has before been possible.

Mrs. C. L. Barber and Dr. Clara M. Davis of Lansing gave some valuable lectures to the juniors in the course in home nursing. The class in house architecture was favored by interesting lectures on plumbing, heating and lighting by Dean Bissell, Prof. Vedder and Prof. Sawyer. Our house director, Mrs. K. M. Cameron, because of her practical experience, assisted in the senior course in institutional management.

The various recitals of the year and the May Festival concerts have been of great good to our music pupils. The new resident instructor in piano, Miss Grace Louise Scott, who is a graduate of the Olivet Conservatory of Music, has been a most helpful addition to the department faculty. Miss Theresa Shier has taken with good success the extra students in music.

Several exhibits of work done in the domestic art department have been of exceptional value and called forth favorable comments from all who saw them. Particularly the color-design work, the basketry, the dressmaking and the cabinet work of the seniors may be mentioned. All regret Miss Coad's resignation which was tendered in June. After three years of efficient service she leaves with the best wishes of all, on account of her approaching marriage.

Important features of the work in physical training, under the direction of Miss Florence Chapman, have been the Folk dances and the out-of-door work consisting of games suited to large play grounds. Miss Chapman has been very successful in her position but will not remain for another year. She plans to spend several months with her family in Europe during the coming autumn.

The average number of hours carried by each teacher through the year is as follows: Miss Coad, domestic art, 19⅔; Mrs. Peppard, domestic art and resident teacher in Howard Terrace, 19; Miss Hunt, professor

of domestic science, 18; Miss Stevens, assistant in domestic science, (half time) 14; Miss Freyhofer, music director, accompanist to college chorus and director of college choir, 22; Miss Scott, music, 22⅓; Miss Shier, assistant in music, 6⅓; Miss Chapman, physical training, health officer and inspector of rooms, 15.

In the spring an invitation was extended by the division to all those interested in home economics to meet at the college for the purpose of organization. Accordingly on May 13th about forty ladies, teachers, dietitians, club women, students and housekeepers, were present and organized the Michigan Branch of the Home Economics Association. Miss Grace Fuller of Ypsilanti was made president and Miss Lenna F. Cooper of the Battle Creek Sanitarium, secretary-treasurer. The chairman of the Home Economics Department of the General Federation of Woman's Clubs, Mrs. Olaf. N. Guldlin, was present and gave an address on "The Mission of Home Economics Workers." A buffet luncheon was served by our senior girls and the day marks the beginning of more general study of household problems in our state.

The dean of the division has accepted several invitations to speak before farmer's institutes, women's clubs and educational meetings, and has been obliged to decline as many more. These have included the Berrien County Federation, the Grand Rapids Ladies Literary Club, the Detroit City Federation, Saginaw, Lapeer, Adrian, Howell, Port Huron, Dowagiac and others. Great interest is shown in home economics and the women of the state wish to know what the Michigan Agricultural College is doing in this line. The new course of study, on the twenty credit basis, ought to give good results, leading to more independent study and scholarly spirit and developing efficiency in all kinds of work.

Respectfully submitted,
MAUDE GILCHRIST,
Dean of Home Economics.

East Lansing, Mich., June 30, 1911.

REPORT OF DEAN OF VETERINARY SCIENCE.

J. L. Snyder, President, Michigan Agricultural College:

Dear President Snyder:—I have the honor to present herewith my first annual report as Dean of the Veterinary Science Division of the Michigan Agricultural College, and thus to submit a review of the work of the college year, September 1st, 1910, to July 1st, 1911.

Veterinary Science, heretofore listed as a department of the Agricultural Division, and as such including more especially instruction in those phases immediately applicable to students of various phases of agriculture, has, under the new form of organization, which I assumed charge of early in September, been considerably broadened in scope and importance through the establishment of a Veterinary Science Division as one of the coordinate divisions of the institution, and the fulfillment of an earlier announcement of a plan to offer education to students contemplating the selection of the veterinary science profession.

At the opening of the fall term affairs of the department were discovered to be in a most chaotic condition, demanding no little effort and time to untangle and adjust this, together with formulating a course of instruction and otherwise attempting the organization of the new division preparatory to beginning regular instruction at the opening of the winter term, the necessary correspondence, the veterinary care to the college live stock and daily class work to junior and senior agricultural students, numbering over fifty, taxed to the utmost the energy at command, more especially as the work was accomplished entirely without assistance. It was during this term that equipment and the services of F. W. Chamberlain, B. S. (Vermont), V. M. D. (Cornell) were secured to facilitate future work of the division.

At the opening of the second or winter term, the teaching force comprised a faculty of four, two immediately connected with the new division and through the cooperation and courtesy of the bacteriological and zoological departments the help of Dr. Ward Giltner and Assistant Professor J. J. Myers respectively, the former giving instruction in histology, the latter physiology, to the sophomore students of the veterinary science division. The remaining work of this term was exceedingly heavy, comprising daily class work with the freshman agricultural students, the daily work with over forty senior and junior agricultural students and for eight weeks two hours each day devoted to the first and second year short course students, or a total of four hours daily given over to students in agriculture. Besides the above and the work already referred to as given by Dr. Giltner and Prof. Myers were scheduled exercises in anatomy, clinical diagnosis and materia medica.

Besides the winter term duties enumerated incident to adequate instruction of the classes listed, and the details of management of the new division, time was found for outside work at several institutes and dairy and agricultural gatherings. Daily class work during dairy week was occupied by lectures and talks upon the anatomy and physiology of the udder, physiology of birth, birth diseases and emergencies. This term also afforded opportunity to entertain the Michigan State Veterinary Medical Association during a two-day meeting which was held by invitation in the veterinary building of the college; an address was also given before the Michigan Breeders' and Feeders' Association and one at the annual "round-up" of the Farmers' Institute.

The schedule for the spring term as outlined in the annual college catalog for sophomore students of the Veterinary Science Division was pursued without alteration and so, also, was the daily class work continued with the senior and junior agricultural students. This work was accomplished by the two veterinarians immediately connected with the division, together with the continued services of Professor Myers and help of Professor Bessey, the latter giving a series of lecture or recitation periods upon poisonous plants especially liable to affect domestic animals. Here again several short trips were made for talks to dairy and agricultural societies. It is our firm belief that a close affiliation of the agriculturists of the state and the Veterinary Science Division cannot but be a mutual benefit, for, as stated in the annual catalog, we shall aim not alone to train men to deal with problems in animal husbandry and sanitation, but likewise to cooperate with stock

owners and veterinary surgeons in the investigation and prevention of animal ailments as far as our resources and facilities will permit.

Toward the close of the spring term the division issued a special bulletin announcing the establishment of the veterinary science course, outlining our proposed schedules, objects and requirements. This document has already found a wide field of usefulness and will unquestionably do much toward circulating the information pertaining to veterinary science instruction at this college.

Mention has been made of the clinical diagnosis course put into operation at the beginning of the winter term and which was continued under a daily schedule throughout the remainder of the college year. It is purposed to conduct this course more especially for the junior and senior veterinary science students but, believing that the work would be more efficient and satisfactory when required, it was begun with the entering sophomore students, thus giving it advertisement and popularity. The aim of the course is to furnish medical and surgical experience as derived only through personal observation, thus rendering the finished student more efficient when brought face to face with actual field practice. Each student is required to write upon the case, to observe the course and progress of disease, healing or repair process, and thus become proficient in clinical observation, administration of treatment or care.

The clinic, as stated, is given daily immediately after the close of the noon hour. The second afternoon class hour is open on the student schedule should occasion require extra time, and for which if used due credit is allotted. The expense of this clinic to the college is negative and to owners of animals comparatively nominal, comprising only actual cost incurred by the division through medicine, materials or keep of animal. During the past two terms the course has assumed considerable popularity, furnishing invaluable aid to students.

The following cases were presented for observation and instruction:

HORSES.		CATTLE.	
Injury	3	Contagious abortion	1
Choke	1	Injury	2
Synovitis	1	Gastro-intestinal catarrh	4
Laryngitis	1	Anti-paritum paralysis	2
Mal-assimilation	1	Mal-assimilation	1
Abscess	2	Abscess	1
Strain inferior sessamoid ligament	2	Tuberculosis	2
Pappilo-fibromata (warts)	5	Endocarditis	3
Dressing teeth	2	Imperforate hymen	1
Recurrent Optholmia	2	Cystic ovaries	2
Laminitis	1	Acute indigestion	1
Tendo-vaginitis (wind puffs)	1	Mammitis	2
Granuloma	1	Tuberculin test	2
Carpitis	1	Ulceration of Sheath	1
		Foreign object in eye	1
		Pneumonia	1

DOGS.		CATS.	
Injury	2	Oophorectomy	2
Oophorectomy	1	Fracture of femur	1
Haemocyst	1	Castration	2
Eczema	1		

PIGS.		SHEEP.	
Poisoning by Arsenate of Lead	1	Mal-assimilation	1
Richits	1		
Castration	1		
Hernia	3		

Cases recorded twice	6
Actual total	86

The course of instruction in veterinary science as outlined for agricultural students was elaborated with the hope of imparting useful knowledge to those contemplating following agricultural pursuits. For the freshman the work embraced lectures upon the exterior conformation of the horse, points constituting unsoundness and a consideration of the appearance of the various animals during health, regarding what constitutes health and what disease as well as distinguishing between normal and abnormal physique, through objective clinical evidence, thus laying a foundation for future veterinary science study and possibly rendering the student more efficient for stock judging work.

In the advanced elective course were included elements of animal hygiene; anatomy and physiology with actual autopsy demonstration; knowledge of agents indicated in the cure, alleviation or prevention of disease, their physiological action; outlines of causes, symptoms and treatment of ailments common to farm animals; a course on animal obstetrics suitable for emergency utility and a discussion of preventative and control measures incident to specific diseases of state importance.

Instruction to students electing the regular work of the veterinary science course is quite a radical change from what has heretofore been undertaken at this institution and assumes more of a routine character entering considerably into an interesting detail of the various courses found listed in the last annual catalog. In this connection I feel that it would be an injustice to the recently established division to fail to urge upon you the necessity of lengthening the course, that it may cover the entire sophomore year rather than commence as now as an elective at the opening of the winter term of that year. The reasons for this request are many, believed to be sound and to warrant careful consideration.

I have the honor to remain, sir,

Very respectfully,

RICHARD P. LYMAN,

Dean of Veterinary Division.

East Lansing, Mich., June 30, 1911.

REPORT OF THE DEPARTMENT OF BACTERIOLOGY.

President J. L. Snyder:

Dear Sir:—The work of the past year may be considered under the following headings:

1. Instruction to four-year students in bacteriology and hygiene.

No particular change has taken place in our instructional work during the past year. The reports of past years will cover this feature very fully.

II. Instruction in Histology.—During the winter term, Dr. Ward Giltner was called upon by the veterinary division to take charge of histology. It was understood that this was only a temporary arrangement. Practically all of his time during the term was devoted to this work.

III. New Veterinary Course.—With the introduction of the new veterinary course there has fallen to the lot of this department additional instructional work. The assuming of pathology by this department means extension. All of the courses in pathology, together with meat and milk inspection, are new. By satisfactory arrangement, Dr. Ward Giltner will assume most of this instructional work.

IV. Short Course Instruction.—Charles W. Brown has spent much of his time during the winter term in assisting in the instruction of dairy students, by means of lectures and laboratory instruction. Since the short course dairy instruction covers two years of eight weeks each, and further, the subjects of butter and cheese have to be considered, the work in bacteriology and hygiene requires much time on the part of the instructor.

Dr Giltner gave a course of lectures, three each week for eight weeks, to the second-year agricultural students.

V. Extension in Instruction.—Miss Zae Northrup, Miss Bell S. Farrand, Dr. Ward Giltner, and myself have given lectures, outside of our regular work, to members of institutes, ladies' clubs, literary clubs, associations, etc. Dr. Giltner, with Mr. Knopf, traveled with the "Better Farming Train" for a period of ten days, giving lectures and demonstrations.

VI. Demonstration Work.—Exhibits have been provided for Excursion Week, Round-Up Institute, Better Farming Train, and a special exhibit for general educational purposes. It is this last exhibit conducted by the entire laboratory force which deserves special consideration, because it was the first attempt to exhibit in some respects the work of this department for the benefit of the public at large. It proved very satisfactory in its comprehensiveness, very instructive to those who visited the exhibit (about 1,000 in all), and gratifying to the laboratory force which gave so much time and effort to its preparation. So far as I know, it was one of the most complete exhibits of the kind ever presented in the United States. Without the most united effort of the entire staff such an exhibit could not have materialized. I am adding the program, which will convey something of its completeness:

You are very cordially invited.

DEMONSTRATION IN BACTERIOLOGY.

Prepared by the Laboratory of Bacteriology and Hygiene, Michigan Agricultural College.

A. GENERAL MICROBIOLOGY.

Modern *Microbiology* includes, besides bacteria, molds, yeasts, protozoa and invisible organisms.

I. Tools of the Bacteriologist.

Microscope, slides, coverglasses, platinum needles, burners, steam and hot-air sterilizer, autoclave, incubator. Test tubes, flasks, petri dishes, wire basket, water-bath. Media, raw materials and finished products. Stains and staining utensils.

Special apparatus: Pasteur flasks, Freudenreich flasks, Koch flasks, Barlow's viability flasks, fermentation tubes.

II. How Microorganisms Grow.

Cider, sterile and with *Saccharomyces cerevisiae* (bread yeast) at various stages of growth. Same with a mold. (*Penicillium*). Cider with yeast in fermentation tube to determine the amount and kind of gas formed.

Milk, sterile and with *Torula*, and *Bacillus subtilis* (both organisms from rancid butter).

Litmus milk, sterile and with *Bacterium lactis acidi* (which makes milk sour) and with *Bacillus mycoides*, (a soil organism).

Potato, sterile and with *Sarcina lutea* (from the air), and with *Bacillus mesentericus* (from soil).

Meat-broth, sterile and with *Bacillus coli* (from the intestine) and with *Mucor* mold.

Meat-gelatin, sterile, with *Bacillus prodigiosus* and with *Streptococcus pyogenes*, (from pus).

Gelatin plate in petri dish from hard cider.

Meat-agar, sterile and with *Bacillus fluorescens* (from water) and with *Staphylococcus pyogenes albus* (from pus).

Agar-plates in petri dishes from street dust.

Blood-serum, sterile and with *Bacillus typhosus* (the typhoid fever bacillus).

III. Counting of Bacteria.

Apparatus for direct counting of blood corpuscles under microscope demonstrated with yeast.

Dilution flasks, sterile pipettes, counting plates.

Plates from 1/100 cc., 1/1,000 cc. and 1/10,000 cc. of dairy milk.

Plates from 1/100,000 cc. of good soil.

IV. Pure Cultures.

A pure culture is the growth of *one* kind of microörganism on a sterilized medium.

1. Molds.

Molds in nature. Molds on horse-dung, fruit, vegetables, preserves, milk and dairy products, maple-sugar, ensilage, moist cotton-seed meal, leather.

Permanent cultures in large culture flasks. Important molds: *Penicillium roqueforti* and *P. camemberti*, help in cheese ripening. *Penicillium expansum* decays apples, *P. italicum* and *P. digitatum* decay oranges. *Aspergillus fumigatus*, causing Aspergillosis of men and animals. *Oidium lactis*, making butter rancid.

Microphotographs and clay models of various molds. Microscope with *Mucor* and with *Aspergillus* (mounted in glycerin).

2. Yeasts.
   Cultivated yeasts: Beer yeast. Bread yeast. Wine yeast. Milk yeast. *Wild yeasts:* Torulae from pickles, from butter, from air, from milk, from ensilage. Photographs, clay models, microscope with Hansen chamber.
3. Bacteria.
   Arranged in biological groups.
   Dairy bacteria, in litmus milk. Soil bacteria on potato. Water and sewage bacteria on broth. Pigment bacteria on agar. Disease bacteria on blood serum. Photogenic bacteria (in the dark room).
   Microphotographs of bacteria. Flagella. Spores. Microscopes with *Bacillus subtilis, Sarcina lutea, Spirillum rubrum, B. prodigiosus* (flagella stain), Spore contrast stain. Clay models.
4. Protozoa.
   Cultures in hay infusion.
   Microscopes with *Paramecium* from soil, living, and with *Sarcosporidium* in tissue (stained). Photographs.

B. BACTERIOLOGY OF DOMESTIC SCIENCE.

I. Preservation and Deterioration of Foods.

Foods can be made to keep either by killing the microörganisms which decompose them, or by preventing them from growing and multiplying. Bacteria are usually killed by heat or antiseptics. Growth is prevented by low temperatures (cold storage), drying, concentrating.

1. Heating.
   Sterilization by one heating.—Fruit preserves, jelly.
   Sterilization by one heating under pressure (generally used in the canning industry).—Tin cans with vegetables and fruit. Spoiled preserves, due to some bacteria very resistant to heat. Pure cultures and photographs of such bacteria. Milk, 6 months old. Different fruit jars and covers in common use.
   Sterilization by intermittent heating.—Recommended for home canning of vegetables, heating on three successive days for about one hour each day. Specimens of students' experiments, one year old. Sterile milk. Wash boiler which may be used for home canning.
   Pasteurization.—Commonly used for milk, because it does not affect the taste. It is accomplished by heating 20 minutes to at least 160°F. (60°C.) and cooling rapidly. Disease germs are killed and the others, decomposing the milk, are greatly reduced. Pasteurized milk does not keep much longer than unheated milk. Pasteurized cider, 6 years old.
2. Drying, Evoporating, Condensing.
   Meat (Dried beef, meat extract). Vegetables. Apples, dates, apricots, raisins, prunes. Milk (Condensed, evaporated, powdered). Cheese (Sapsago). Eggs, dried whites for clarifying soups, coffee, etc. Malt extract.
3. Salting.
   Brined cucumber pickles. Common household method. Prevention of scum growth by sealing the pickles air tight with oil. Pure culture of scum yeast.
   Salted meats and fish (dry and brined). Dried cod. Corned beef. Eggs preserved in salt brine. Salted butter.
   Scums and pure cultures of brined pickles, olives, dill pickles, brined meat and fish.
4. Sugaring and Preserving.
   Jellies, preserves and marmalades, inoculated, with and without paraffin on the surface. Candied fruits—plums, pine-apple, cherries, etc.
5. Oil.
   Sardines.
6. Chemical Preservatives.
   Boric acid. Salicylic acid. Benzoate of soda (1 gr. weighed out and placed beside 100 cc. of ketchup). Saltpeter for meats (1 oz. to 25 lbs. of beef). Formalin in milk (.05%). Hydrogen peroxide in milk (.5%). Ethyl alcohol. Eggs preserved in water-glass.

7. Smoking.
Smoked meat. Ham, bacon.
Smoked fish. Halibut, herring.
Coal tar products. Creosote.

8. Spices.
Fruit cake. Mince-meat. Ketchups of various sources—some with molds and some fermenting. Oil of cloves, cinnamon, allspice, mustard.

9. Preservation by Fermentation.
Preservation is secured through the production of large amounts of acid which prevents undesirable bacterial growth. Sauerkraut, brine pickles, dill pickles, fruit juices, sour cream butter, cheese. Fresh meat preserved temporarily in buttermilk and in vinegar. Pure cultures from sauerkraut, vinegar and milk scums.

II. Bread.

1. Salt-rising Bread.
Salt-rising bread is risen by a bacterium (*Bacterium aerogenes*) which produces large quantities of gas. Pure culture of germ under the microscope, in milk and on agar. Gas production in fermentation tube. Samples of corn meal, canaille and sweet milk where *Bact. aerogenes* is ordinarily found. Exhibit two loaves of bread; one made at bakery, one made in the laboratory from a pure culture of the germ.

2. Yeast Bread.
Fleischmann's compressed yeast cake. Magic yeast cake. (Demonstrate colonies from a cake 4 years old, still alive.) Slimy, moldy and pigmented breads.

III. Vinegar.

Stains of acetic bacterium and yeast involved in the manufacture of vinegar. Yeast grown in sterilized cider showing alcoholic fermentation (hard cider). Acetic bacterium in sterile cider without yeast. Yeast and acetic bacterium grown together producing vinegar.

Commercial culture for vinegar production.

Cider vinegar, tomato vinegar. Impure vinegar. Vinegar eels.

Quick vinegar process.

C. DAIRY BACTERIOLOGY.

I. Milk.

1. Bacteria in Milk.
Market milk—plates from fresh sample. Certified milk—plates from fresh sample. Bacteria from udder of cow—plates from fore-milk, middle milk, and strippings. Effect of straining upon number of bacteria—plates made before and after straining, show strainer. Effect of separation upon numbers—plates from cream, milk, and separator slime. Microscope—stain from market milk showing cells and bacteria. Pure cultures in litmus milk of a number of different milk microörganisms.

2. Contamination of Milk.
Tubes of sterile milk, to which has been added a piece of sterile straw, of sterile hay and some sterile soil. To which has been added straw, hay, litter from barn floor, cow's hair, soil, etc.
Plates showing number of microörganisms in barn air (before and after feeding), in laboratory air, in clean milk bottle (before and after steaming), in poorly cleaned milk utensils, as pails, strainers, separators, etc., and on hands (before and after washing).

3. Constituents of Milk, Butter and Cheese.
Samples of the different constituents and table showing percentages.
Action of microörganisms upon casein—shown by milk agar plates and milk cultures.
Action upon lactose—acid in litmus milk and carbonate lactose agar plates; gas in fermentation tubes of whey, lactose agar tubes.
Action upon butter fat—shown by comparison of growth of certain microörganisms upon synthetic agar and fat-synthetic agar plates.
Microscope showing fat globules in whole milk.

4. Fermentation of Milk.

Spontaneous fermentation.

(a) Flasks of milk from a number of different sources kept for a week at room temperature (70°F.).

(b) Some of the same milks kept at 45°F.

Acid fermentation—ordinary market milk (loppered), sterile litmus milk inoculated with acid-producing organisms, and a pure culture starter 6 weeks old.

Gaseous fermentation—sterile milk in fermentation tubes inoculated with *Bact. aerogenes*, with lactose fermenting yeasts; also a flask of milk showing evolution of gas and a gassy curd.

Sweet curd fermentation—litmus milk inoculated with rennet-producing organisms.

Ropy fermentation—milk inoculated with a ropy milk bacterium.

Bitter milk fermentation—milk inoculated with bitter milk bacteria.

Color fermentation—plain milk inoculated with chromogens.

Alcoholic fermentation—Matzoon, Yoghourt, etc.

5. Moldy Milk.

Milk upon which is growing *Oidium lactis*, *Mucor*, *Penicillium*, *Aspergillus*.

6. Starter Bacteria and Some of Their Work.

Cultures (milk, agar and broth). Power of reduction (cultures in litmus milk, methylene blue milk). Antiseptic influence towards other bacteria (a flask of milk inoculated with starter compared with another flask of same milk not inoculated). Their work which is made use of in dairy—sweet milk vs. sour milk, sweet cream vs. ripened cream, sweet cream butter vs. ripened cream butter, cottage cheese, etc.

7. Preserved Milks.

Sterilized sweet milk—flask of milk 4 months old. Evaporated milk. Condensed whole milk and condensed skim milk. Dried milk (milk powder).

II. Butter.

1. Bacteria in Butter.

Plates from sweet cream butter and from fresh ripened cream butter. Plates from butter 10 days, 18 months and 4 years old. Plates from butter on 12% salt agar.

2. Storage Butter.

Butter that has been kept outside north window for 30 days. Sample of same butter kept in same place, but protected from light. Samples of butter 18 months and 4 years old. Uncolored butter 3 years old made from sterilized cream with pure cultures.

3. Moldy Butter.

Samples of uncolored butter with different molds as *Penicillium*, *Aspergillus*, *Mucor*, *Oidium*.

Print in paper with molds growing upon it.

Other half of same print from which paper was removed.

4. Oleomargarine.

Plates showing germ count.

III. Cheese.

1. Bacteria in Cheese.

Fresh and ripe Michigan cheese and plates showing germ count. Microscopes showing bacteria in sections of fresh and ripe cheese.

2. Cheese Ripening.

Unripened cheeses—cottage cheese, Neuf-chatel. Ripened cheese—Cheddar, Edam, Swiss, Brick. Cheeses ripened with molds—Roquefort, Camembert. Abnormal moldy spots on cheese. Bulged and gassy cheese and germ causing it. Microscope showing section of Roquefort cheese.

D. SANITATION.

I. Water Bacteriology.

Water from rock well and from surface well compared with sewage from river.

1. Bacteriological Analysis.

   Agar shake (litmus lactose) to test a large quantity (100 cc.) of water for acid and gas-producing germs.

   Litmus lactose agar (without salt) plates and gelatin (without salt) plates inoculated with 1 cc., 0.5 cc., and 0.1 cc. of water to show comparative germ count and acid colonies and liquefiers.

   Broth and litmus milk tubes inoculated with 1 cc., 0.5 cc. and 0.1 cc. of water to test small amounts of water for germ content and kind of germs present.

   Dextrose, lactose and saccharose fermentation tubes to show gas production.

   Tubes of nitrate broth and Dunham's peptone solution inoculated with water germs to show the production of nitrates and indol respectively.

   Pure cultures of *B. coli* and *B. typhosus* for comparison on the above different media.

   Hanging drop of *B. coli* under microscope.

2. Bacterial Products in Water.

   Color test for nitrates, nitrites, free ammonia, and chlorine. Samples of each water compared in Nessler tubes and parts per million of each noted and the significance of each.

3. Domestic Water Filters.

   Unglazed porcelain. Charcoal.

4. Charts.

   Showing contamination of water supplies.

II. Sewage.

1. Bacteriological Analysis.

   As above. Drop of sewage under microscope.

2. Bacterial Products.

   (Same as under water analysis.)

3. Sewage Disposal.

   Aerobic—Construction of filter beds. Anaerobic—Model of septic tank.

III. Communicable Diseases.

1. Common Miscellaneous Sources of Diseases.

   Plates made from dried saliva, dirt from walks (drag a cloth one block on Washington avenue to show germs gathered by long skirts), public drinking cup (obtain with sterile moist swab and smear over sterile agar), public telephone—receiver and transmitter—(use sterile moist swab), towel used by the public (soak part in sterile water), door knobs and jambs (use sterile moist swab), infected cloth, before and after boiling, before and after ironing, hands (washed in sterile water and with some disinfectant), public comb, razor, food exposed to dust of street, pet animals, library books, money, etc.

2. Bacteria in Air.

   Plates containing sterile agar exposed one minute to—outside air (campus and city of Lansing), air in lower corridor Women's Bldg. while girls are going to classes, air of room (before, during and after sweeping), air of room before, during and after cleaning with vacuum cleaner, air of room (dusting with dry and damp cloth).

   List of diseases transmitted by air.

3. Microscopic Demonstration of Sources.

   Stained specimens of saliva—tuberculous sputum. Tartar from the teeth. Public drinking cup. Public telephone. Pus direct from suppurating wounds.

4. Insect Carriers of Disease.

   House fly. *Musca domestica.* Diseases transmitted by house fly—typhoid fever, dysentery and all other intestinal diseases, tuberculosis. Chart to show *how* flies carry disease by means of their feet, also by means of their excreta. The house fly does not bite. Fly posters. Fly tracks on agar plate. Breeding place and rapidity of breeding on placard.

Mosquitos (*Anopheles*, disease-carrying. *Culex*, harmless). Diseases transmitted—yellow fever, malaria and filariasis. Chart to show how mosquitos carry disease. Chart showing how to distinguish ordinary from disease-carrying mosquitos.

Fleas (*Pulex cheopis*).—Rat fleas carry bubonic and septicemic plague. Common flea or dog flea (*Ctenocephalus serraticeps*) is said to be a carrier of infantile paralysis.

Tsetse fly.—(*Glossina palpalis*). Carrier of *Trypanosome gambiense*, which produces sleeping sickness.

Texas fever ticks (*Boophilus bovis*).—Carrier of *Piroplasma bigeminum* the protozoa of Texas cattle fever.

IV. Chemical Disinfectants.

Coal tar products (phenol, cresol, petroleum, creosote). Products of distillation of wood (creosote, methyl alcohol). Anilin dyes. Mineral acids and salts, (mercuric bichloride, borax, copper sulphate, ferrous sulphate, calcium hypochlorite or bleaching powder). Organic acids (acetic, lactic, salicylic acids). Organic salts (benzoate of soda), chlorine, iodine, sulphur, dioxide. Formaldehyde. Alcohol. Hydrogen peroxide.

V. Physical Disinfectants.

Cold—Ice box or refrigerator.

Heat—Sterilization or pasteurization by boiling (water, foods), by steam (clothing), or by hot air (bedding), cremating.

Sunlight—Culture of *B. prodigiosus* killed by light.

E. MICROBIOLOGY OF SOILS.

I. Demonstration of Microorganisms in soil.

A sample of soil direct from the field from which plates have been poured, hanging drops and stained slides prepared. Comparative numbers in different soil types. With the same dilutions, plates have been poured from sands, clays, loams, mucks, etc., from the same and from different localities. Comparative numbers in the different soil strata. Plates demonstrating the constantly decreasing number of organisms in surface, subsurface, and subsoil.

II. Functions of Microorganisms in Soil.

1. Action Upon Mineral Matter.

As a rock decomposes microörganisms take hold and grow and by their life and death followed by that of higher plants fertile soil is produced. The insoluble compounds of phosphorus, sulphur, iron, etc., are made soluble by the activity of microörganisms. Demonstrated by increased amount of soluble phosphate when inoculated.

2. Action Upon Organic Matter.

Decomposition of organic matter in soil as elsewhere is largely due to microörganisms. Demonstrated by there being no decomposition when bacteria are killed. This is true of all forms of organic decay. Humus production, cellulose decomposition, commercial organic fertilizers' availability are demonstrated. In this decomposition, there is a great deal lost in the gaseous form but recovered by other bacteria. Shown in the "Nitrogen Cycle." Decomposition in the manure heap with attendant losses. Straw decay in manure shown to be caused by bacteria.

III. Factors Influencing Soil Microorganisms.

1. Cultivation.

Plates poured to show varying numbers on fields managed in different manners.

2. Liming

Or acidity and alkalinity. Shown by plating as above and also data.

3. Influence of Methods of Managing Manures.

Upon the microbial activity and elemental losses.

IV. Individual Species.

There are certain bacterial species of prominent importance in the soil.

1. Pseudomonas Radicicola.

The organisms of commercial cultures for inoculating legumes. Known also as legume or nodule-forming bacterium. Growth of nodule on root showing its prevalence on all legumes. Demonstration of failure of cross inoculation. Characteristics of the species shown by stained slides, cultures on special media. Composition of media. Commercial production of cultures showing method of obtaining bacteria from nodule, testing of these bacteria on plants grown from sterile seeds and on sterile agar or quartz sand. Methods of seed sterilization. Commercial cultures of organisms for alfalfa, alsike clover, red clover, white clover, vetch, beans, soy beans, peas, cowpeas, sweet peas. Method of shipping the cultures. Charts showing the distribution of the cultures throughout the state.

2. Azotobacter.

An organism which assimilates nitrogen from the atmosphere. Prevalence, results from inoculation. Cultures, plates, and slides to show its characteristics.

3. Other Species.

Such as ammonifiers (decomposing organic matter to ammonia), nitrifiers (forming nitric acid), denitrifiers (breaking down nitric acid), etc.

F. ANIMAL PATHOLOGIC BACTERIOLOGY.

I. Disease Producing Organisms.

1. Cultures of Disease-producing Organisms.

Specific: 1. *Bact. tuberculosis.* 2. *Bact. anthracis.* 3. *Bact. abortus* 4. *Bact. mallei.* 5. *B. cholerae suis.* 6. *Bact. diphtheriae.* 7. *B. typhosus*, etc.

Non-specific: Pus-producing organisms.

2. Microscopic Demonstration.

Bact. tuberculosis, human, bovine, avian. *B. typhosus*, *Bact. diphtheriae*, pyogenic bacteria.

3. Photomicrographs of Disease-producing Bacteria.

Bact. tuberculosis in sputum. *Bact. diphtheriae*, Negri bodies, (found in hydrophobia or rabies). *Gonococcus. B. typhosus. Bact. abortus* (Bang) from cotyledon.

Photographs showing—Turkey sick of entero-hepatitis or blackhead. Hen with infected feather follicles. Macroscopic agglutination of *B. cholerae suis*. Subdural inoculation of rabbit, etherized. Intraperitoneal inoculation of rabbit. Subcutaneous inoculation of rabbit. Inoculated rabbit in cage. Weighing guinea pig before treatment.

II. Diseases.

1. Tuberculosis.

Bovine—tubercles in lung, lymph glands, mammary glands, liver, spleen, heart, peritoneum. Porcine—tubercles in skin, bone, joints, mammary glands, testicle, adrenal, submaxillary lymph gland, lungs, liver, heart. Avian—tubercles in lung, liver, spleen, intestine.

Photographs of healthy and tuberculous cows, the latter both apparently healthy and visibly diseased. Outfit for collecting human tuberculous sputum and method for demonstrating presence of germs.

2. Hog Cholera.

Diseased organs in hog cholera.

3. Other Animal Diseases.

Actinomycosis (lumpy jaw) in head, liver, diaphragm of cattle. Infectious abortion—diseased cotyledons. Entero-hepatitis (black head) in turkeys. Tumors and other pathological conditions. Animal parasites and their effect on animals.

4. Maps.

showing distribution of hog cholera, tuberculin testers and contagious abortion of cattle in Michigan.

III. AGENCIES FOR COMBATING DISEASES.

1. ANIMALS FOR EXPERIMENTAL WORK.

   Guinea pigs, rabbits, rats.

2. NATURAL AND ARTIFICIAL REMEDIES.

   Natural: Leucocytosis, agglutination (macroscopic and microscopic). Haemolysis.

   Artificial: Antitoxins (diphtheria and tetanus). Apparatus for collecting material for diagnosis of diphtheria and typhoid fever. Smallpox vaccine.

   Hog cholera—serum and virus. Berkefeld (infusorial earth) filter and filtration of hog cholera virus by suction. Pasteur-Chamberland filter (unglazed porcelain) and filtration of hog cholera virus by air pressure. Syringes for injecting serum and virus. Photographs showing process of serum manufacture and method of using serum.

   Tuberculin, and how it is made. Syringe, chart, thermometer and disinfectant. Preparation of autogenous vaccines.

NOTICE.—The stables are not open to visitors.

VII. A Text Book in Bacteriology. Instructional work in bacteriology in the various agricultural institutions of this country has been greatly hampered because of the lack of a suitable text book for class work. Hoping to fill this long-felt want, and, at the same time, to secure as authoritative a work as possible, the head of this department has cooperated with nineteen other bacteriologists of the United States and Canada, as editor, in the preparation of a text-book. The book is now in galley proof form, and will probably be ready for next year's classes. While considerable energy and effort has been put forth in the preparation of this book, we fully feel that this work will be a great benefit to agriculture as viewed from the standpoint of microbiology, and we trust that it will serve as one of the factors in building up the pedagogy of agriculture.

VIII. The Health of This Institution. This year, the college has been visited by epidemics of several diseases, namely, mumps, measles, scarlet fever, chicken pox, and typhoid fever. None of these diseases appeared before the middle of January, but since then they have been more or less constant with the exception of typhoid fever. At no time, however, did they gain such a foothold as to materially interfere with the class work of the institution. This is probably owing to a persistent effort in eliminating cases as fast as they appear, from the dormatories and rooming houses in the vicinity. As soon as a student is found to have contracted any contagious disease, he is at once isolated in our cottage hospitals. The room is then fumigated. This system works very nicely, unless walking cases appear, when the individual is not aware that he has the disease. In such instances, the diseases are readily scattered. This has been the case this year, so far as mumps and measles were concerned.

Peculiar interest centers in the epidemic of typhoid fever, the first case of which appeared April first. On March 11th, the lady in charge of Club D stated over the telephone that typhoid fever was suspected to exist on one of the farms furnishing milk to the Club. The man living on the farm denied the presence of typhoid fever. Inasmuch as there was some suspicion, the milk supply was immediately cut off. The water used by the family was analyzed by this laboratory, and condemned. Little attention, however, was given to this matter by the

people on the farm until the second case appeared on the farm in April. However, there was no connection between the milk supply of Club D and the farm after March 11th. On April first, the first student came down with typhoid fever at the college, and was taken to the general hospital. Three or four others came down during the following week, and during the month the number reached thirteen in all. All of these had secured their meals at Club D with the exception of one. Seven of the thirteen were treated at the college hospitals; six were treated elsewhere, some having contracted the disease and as soon as ailing, went home, while others contracted the disease before their return from their vacation. Of the seven treated at the college, all recovered; of the six treated elsewhere, in one place and another, three or fifty per cent died.

This is in brief the history of the typhoid epidemic occurring during the months of March, April, and May the past year. Of course, we always have with us from time to time sporadic cases of typhoid fever which are brought in, the disease having been contracted elsewhere.

Miss Zae Northrup has kept a detailed statement of the other contagious diseases cared for at the cottage hospitals, and has submitted a report, which I now add:

CONCERNING THE 1911 EPIDEMICS OF CONTAGIOUS DISEASES.

About a week after the beginning of the winter term, contagious diseases appeared at the college, many new cases developing each succeeding week of the term with scattering cases during the spring term.

If the cottage system of isolation hospitals had not existed, this epidemic might have reached alarming proportions. There were several times when the cottages were so overcrowded that it seemed as if no one else could possibly be admitted, but there oftentimes had to be room for one more. The cottages, which are provided with two wards comfortably housing only three patients each, many times contained ten or twelve patients. This extraordinary number of patients necessitated the buying of more beds and bedding and other permanent supplies.

The plan has been pursued of keeping one kind of contagious disease confined to one hospital where possible; the mumps cases, however, were so numerous this last winter that two cottages had to be used.

The diseases in the order of their prevalence were mumps, measles, typhoid fever, scarlet fever and chicken-pox.

One hundred and eight cases, mostly students, have been cared for in the cottage hospitals since the 12th of January, 74 of mumps, 25 of measles, 4 of scarlet fever, 3 of typhoid and 2 of chicken-pox. Ninety occurred during the winter term, an average of 9 new cases each week; of these, 26 were short course men, 59 regular students, and 5 subfaculty. Of the total number, 108, 13 were women.

The 74 mumps patients spent a total of 777 days in the hospitals; 25 measles patients, 288 days; 4 scarlet fever patients, 94 days. Altogether the 108 cases since January 12th have spent (to June 19th) a total of 1,333 days, or 3 years, 7 months and 28 days within hospital walls.

At the rate of $5.00 per week for students, the income at the end

of the college year will approximate $975.00. The total amount paid nurses also approximates $975.00. In addition to this amount are the sums spent for food, medicines, disinfectants, laundry and miscellaneous supplies which amounts are given below:

Groceries and supplies (medicine)	$247 20
Meat	52 25
Milk, cream, butter and ice	101 78
Eggs and chickens	75 48
Laundry	133 47
Disinfectants	189 70
Making a total of	$799 88

to June 15th, 1911. This amount does not include the extra permanent supplies which had to be purchased, nor the extra labor for keeping the hospitals in running order, disinfecting rooms and clothing, obtaining supplies from the different sources, running the hand ambulance, etc.

From these figures it will be noted that such an epidemic is a financial loss both to the college and to the student.

ZAE NORTHRUP.

I have no details to add regarding the general hospital in charge of Miss Ketchum, as nurse, but I can make this general statement: The general hospital has become a rendezvous for students suffering from temporary and light ailments who go there to convalesce. From time to time, serious cases are cared for which are not regarded as contagious.

Dr. Bruegel, the health officer, Miss Northrup, Miss Goritz, Miss Ketchum, and Mr. Penner, all who have been so diligent in looking after the wants of the sick the past year deserve the greatest consideration and most heartfelt thanks, for one not familiar with the situation at such a time can scarcely appreciate the vast amount of work entailed.

In addition to the handling of the diseases of patients, Miss Northrup has analyzed many samples of water throughout the year, simply as a safeguard to the student body. I now give the report of these water analyses which she has submitted.

WATER ANALYSES.

Since July 1st, 1910, many samples of water have been analyzed, from the college system, from the East Lansing city water supply, from the Chase-Angell system, and from miscellaneous sources.

In these samples, only the bacteriological and chemical analyses necessary for establishing sewage pollution were undertaken.

The average bacterial count per cc. for the college water was 21, the number ranging from 7 to 30; for the East Lansing city water, 175, the number ranging from 19 to 306 per cc., and the Chase-Angell water averaged about 125 per cc., ranging from 6 to 292 in the samples analyzed. The bacterial count of well waters was very variable, ranging from 0 to 108,000 per cc., the average being 12,469 per cc.

Only four wells were found to be contaminated and these were private water supplies. It was advised in each case that the use of this water

for any and all purposes be discontinued unless boiled. (This was not done immediately in all cases, which fact may account directly or indirectly for some of the sporadic cases of typhoid fever at the college this past year.)

ZAE NORTHRUP.

IX. Serum and Culture Work of the Department.—While the serum and culture work strictly belongs within the province of college operations, for various reasons the detailed report will be given in connection with Experiment Station work. For details, therefore, of this work I refer the reader to the Experiment Station report of this department.

This department has been exceedingly busy the past year, each member of the staff occupied really beyond his limitations. Industry has been in the atmosphere. The results have been most gratifying. This condition of affairs, most pleasing to me, is due to that commendable spirit emanating from every member of the staff which makes for progress. My sincere gratitude, so far as I am personally concerned is due each, Dr. Otto Rahn, Dr. Ward Giltner, Charles W. Brown, W. A. Wentworth, Miss Zae Northrup, Miss Bell Farrand, Miss Lulu M. Smith, Miss Louise Rademacher, Warren S. Robbins, Miss Carolyn D. Goritz, and R. W. Penner.

Very respectfully submitted,
CHARLES E. MARSHALL.
Professor of Bacteriology and Hygiene.

East Lansing, Mich., June 30th, 1911.

REPORT OF THE DEPARTMENT OF MATHEMATICS.

President J. L. Snyder:

Dear Sir:—I submit herewith my report as head of the Department of Mathematics for the college year 1910-1911.

We have been so fortunate as to retain our regular teaching staff of the year before, and, in consequence, the work of the department has increased in efficiency. The following is a list of the members of the department in order of seniority of appointment:

Warren Babcock, B. S., Professor of Mathematics.
M. F. Johnson, B. S., Instructor.
S. E. Crowe, B. A., Instructor.
J. E. Robertson, B. S., Instructor.
E. E. Beighle, B. S., Instructor.
L. C. Emmons, B. S., Instructor.
K. E. Hopphan, B. S., Instructor.
H. A. Snepp, B. A., Instructor.
R. H. Reece, B. S., Instructor.

In addition to the above named, Mr. R. L. Nye taught four sections during the winter term.

Following appears a schedule of the class room work of the department arranged by terms:

Fall Term 1910.

Class.	Subject.	No. of course.	Instructor.	Classroom.	Hour of meeting.	No. of hrs. per week.	No. of students in class.
Sub-fresh.....	Ag. and W. Alg...	Math. 1...	Mr. Beighle.......	100 Ag. Hall......	8:55- 9:50	5	15
Sub-fresh.....	Ag. and W. Alg...	Math. 1...	Mr. Beighle.......	100 Ag. Hall......	10:45-11:40	5	16
Sub-fresh.....	Ag. and W. Alg...	Math. 1....	Mr. Robertson....	101 Ag. Hall......	10:45-11:40	5	18
Sub-fresh.....	Ag. and W. Alg...	Math. 1....	Mr. Robertson....	101 Ag. Hall......	8:55- 9:50	5	16
Sub-fresh.....	Ag. and W. Alg...	Math. 1....	Mr. Crowe........	102 Ag. Hall......	10:45-11:40	5	16
Sub-fresh.....	Eng. Alg.........	Math. 1c...	Mr. Emmons......	8 College Hall...	2:30- 3:25	5	21
Sub-fresh.....	Eng. Alg.........	Math. 1c...	Mr. Snepp.........	103 Ag. Hall......	8:55- 9:50	5	23
Freshmen....	Eng. Alg.........	Math. 1e...	Prof. Babcock.....	2 College Hall...	9:50-10:45	5	20
Freshmen....	Eng. Alg.........	Math. 1e...	Mr. Reece........	301 Eng. Hall.....	10:45-11:40	5	20
Freshmen....	Eng. Alg.........	Math. 1e...	Mr. Hopphan.....	8 College Hall...	8:55- 9:50	5	12
Freshmen....	Eng. Alg.........	Math. 1e...	Mr. Hopphan.....	8 College Hall...	9:50-10:45	5	22
Freshmen....	Eng. Alg.........	Math. 1e...	Mr. Crowe......	102 Ag. Hall......	8:55- 9:50	5	12
Freshmen....	Eng. Alg.........	Math. 1e...	Mr. Snepp........	103 Ag. Hall......	9:50-10:45	5	21
Freshmen....	Eng. Alg.........	Math. 1e...	Mr. Snepp........	103 Ag. Hall......	12:40- 1:35	5	20
Freshmen....	Eng. Alg.........	Math. 1e...	Mr. Emmons......	8 College Hall...	12:40- 1:35	5	19
Freshmen....	Eng. Alg.........	Math. 1e...	Mr. Johnson......	2 College Hall...	1:35- 2:30	5	21
Freshmen....	Eng. Geom........	Math. 2d..	Mr. Emmons......	101 Ag. Hall......	8:00- 8:55	5	23
Freshmen....	Eng. Geom........	Math. 2d...	Mr. Emmons......	8 College Hall...	1:35- 2:30	5	18
Freshmen....	Eng. Geom........	Math. 2d...	Mr. Snepp........	103 Ag. Hall......	8:00- 8:55	5	22
Freshmen....	Eng. Geom........	Math. 2d...	Mr. Snepp........	103 Ag. Hall......	1:35- 2:30	5	19
Freshmen....	Eng. Geom........	Math. 2d...	Mr. Beighle.......	100 Ag. Hall......	8:00- 8:55	5	23
Freshmen....	Eng. Geom........	Math. 2d...	Mr. Beighle.......	100 Ag. Hall......	1:35- 2:30	5	18
Freshmen....	Eng. Geom........	Math. 2d...	Mr. Hopphan.....	8 College Hall...	8:00- 8:55	5	22
Freshmen....	Eng. Geom........	Math. 2d...	Mr. Hopphan.....	301 Eng. Hall.....	1:35- 2:30	5	19
Freshmen....	Ag. and W. Alg...	Math. 1b...	Mr. Johnson......	100 Ag. Hall......	9:50-10:45	5	21
Freshmen....	Ag. and W. Alg...	Math. 1b..	Prof. Babcock.....	2 College Hall...	8:00- 8:55	5	29
Freshmen....	Ag. and W. Alg...	Math. 1b...	Mr. Reece........	102 Ag. Hall......	8:00- 8:55	5	23
Freshmen....	Ag. and W. Alg...	Math. 1b...	Mr. Reece........	301 Eng. Hall.....	9:50-10:45	5	22
Freshmen....	Ag. and W. Alg...	Math. 1b...	Mr. Reece........	301 Eng. Hall.....	12:40- 1:35	5	20
Freshmen....	Ag. and W. Alg...	Math. 1b...	Mr. Reece........	302 Eng. Hall.....	3:25- 4:20	5	17
Freshmen....	Ag. and W. Alg...	Math. 1b..	Mr. Hopphan.....	401 Eng. Hall.....	12:40- 1:35	5	21
Freshmen....	Ag. and W. Alg...	Math. 1b...	Mr. Crowe........	102 Ag. Hall......	9:50-10:45	5	21
Freshmen....	Ag. and W. Alg...	Math. 1b...	Mr. Crowe........	8 College Hall...	3:45- 4:20	5	15
Freshmen....	Ag. and W. Alg...	Math. 1b...	Mr. Robertson....	101 Ag. Hall......	1:35- 2:30	5	19
Freshmen....	Ag. and W. Alg...	Math. 1b...	Mr. Robertson....	101 Ag. Hall......	9:50-10:45	5	24
Freshmen....	Ag. and W. Alg...	Math. 1b...	Mr. Johnson......	100 Ag. Hall......	10:45-11:40	5	20
Sophomores...	Anal. Geom.......	Math. 5....	Mr. Johnson......	2 College Hall...	12:40- 1:35	5	19
Sophomores...	Anal. Geom.......	Math. 5....	Prof. Babcock.....	2 College Hall...	10:45-11:40	5	19
Sophomores...	Anal. Geom.......	Math. 5....	Mr. Emmons......	8 College Hall...	10:45-11:40	5	21
Sophomores...	Anal. Geom.......	Math. 5...	Mr. Crowe........	102 Ag. Hall......	12:40- 1:35	5	25
Sophomores...	Anal. Geom.......	Math. 5....	Mr. Beighle.......	100 Ag. Hall......	12:40- 1:35	5	25
Sophomores...	Anal. Geom......	Math. 5...	Mr. Robertson....	101 Ag. Hall......	12:40- 1:35	5	25

Spring Term 1911.

Class.	Subject.	No. of course.	Instructor.	Classroom.	Hour of meeting.	No. of hrs. per week.	No. of students in class.
Sub-fresh.....	Mensuration......	Math. 3....	Mr. Johnson......	2 College Hall...	8:55- 9:50	5	13
Sub-fresh.....	Mensuration......	Math. 3....	Mr. Emmons......	8 College Hall...	2:30- 3:25	5	18
Sub-fresh.....	Eng. Geom.......	Math. 2c...	Mr. Crowe........	8 College Hall...	8.00- 8:55	5	12
Sub-fresh.....	Eng. Geom.......	Math. 2c...	Mr. Crowe........	8 College Hall...	1:35- 2:30	5	16
Sub-fresh.....	Ag. and W. Geom .	Math. 2a...	Mr. Snepp........	2 College Hall...	1:35- 2:30	5	17
Sub-fresh.....	Ag. and W. Geom.	Math. 2a...	Mr. Reece........	103 Ag. Hall......	1:35- 2:30	5	19
Sub-fresh.....	Ag. and W. Geom.	Math. 2a...	Mr. Hopphan.....	101 Ag. Hall......	1:35- 2:30	5	22
Sub-fresh.....	Ag. and W. Geom.	Math. 2a...	Mr. Beighle.......	8 College Hall...	8:55- 9:50	5	19
Freshmen.....	Eng. Trig........	Math. 4b...	Mr. Emmons......	2 College Hall...	12:40- 1:35	5	19
Freshmen....	Eng. Trig.........	Math. 4b...	Mr. Hopphan.....	101 Ag. Hall......	12:40- 1:35	5	15
Freshmen....	Eng. Trig.........	Math. 4b...	Mr. Reece........	8 College Hall...	9:50-10:45	5	23
Freshmen....	Eng. Trig.........	Math. 4b...	Mr. Reece........	103 Ag. Hall......	12:40- 1:35	5	15
Freshmen....	Eng. Trig.........	Math. 4b...	Mr. Snepp........	2 College Hall...	8:00- 8:55	5	16
Freshmen....	Eng. Trig.........	Math. 4b...	Mr. Snepp........	2 College Hall...	9:50-10:45	5	23
Freshmen....	Eng. Trig.........	Math. 4b...	Mr. Robertson....	100 Ag. Hall......	9:50-10:45	5	23
Freshmen....	Eng. Trig.........	Math. 4b...	Mr. Johnson......	2 College Hall...	2:30- 3:25	5	19
Freshmen....	Ag. Trig..........	Math. 4a...	Mr. Robertson....	100 Ag. Hall......	8:00- 8:55	3	22
Freshmen....	Ag. Trig..........	Math. 4a...	Mr. Robertson....	100 Ag. Hall......	2:30- 3:25	3	20
Freshmen....	Ag. Trig..........	Math. 4a...	Mr. Hopphan.....	101 Ag. Hall......	8:00- 8:55	3	21
Freshmen....	Ag. Trig..........	Math. 4a...	Mr. Hopphan.....	101 Ag. Hall......	9:50-10:45	3	16
Freshmen....	Ag. Trig..........	Math. 4a...	Mr. Beighle.......	100 Ag. Hall......	1:35- 2:30	3	26
Freshmen....	Ag. Trig..........	Math. 4a...	Mr. Beighle.......	102 Ag. Hall......	2:30- 3:25	3	20
Sophomores...	Calculus..........	Math. 6b...	Prof. Babcock.....	2 College Hall...	10:45-11:40	5	19
Sophomores...	Calculus..........	Math. 6b...	Mr. Emmons......	8 College Hall...	10:45-11:40	5	18
Sophomores...	Calculus..........	Math. 6b...	Mr. Johnson......	100 Ag. Hall......	10:45-11:40	5	20
Sophomores...	Calculus..........	Math. 6b...	Mr. Robertson....	100 Ag. Hall......	12:40- 1:35	5	18
Sophomores...	Calculus..........	Math. 6b...	Mr. Crowe........	8 College Hall...	12:40- 1:35	5	18
Sophomores...	Calculus..........	Math. 6b....	Mr. Beighle.......	102 Ag. Hall......	12:40- 1:35	5	18

Winter Term 1911.

Class.	Subject.	No. of course.	Instructor.	Classroom.	Hour of meeting.	No. of hrs. per week.	No. of students in class.
Sub-fresh.....	Eng. Alg.........	Math. 1d...	Mr. Hopphan.....	100 Ag. Hall......	10:45-11:40	5	24
Sub-fresh.....	Eng. Alg.........	Math. 1d...	Mr. Nye..........	2 College Hall...	8:00- 8:55	5	16
Sub-fresh.....	Eng. Geom.......	Math. 2....	Mr. Reece........	103 Ag. Hall......	1:35- 2:30	3	19
Sub-fresh.....	Eng. Geom.......	Math. 2....	Mr. Snepp........	102 Ag. Hall......	1:35- 2:30	3	21
Sub-fresh.....	Ag. and Wm. Alg..	Moth. 1a...	Mr. Robertson....	100 Ag. Hall......	8:55- 9:50	5	19
Sub-fresh.....	Ag. and Wm. Alg..	Math. 1a...	Mr. Nye..........	101 Ag. Hall......	10:45-11:40	5	17
Sub-fresh.....	Ag. and Wm. Alg..	Math. 1a...	Mr. Beighle.......	301 Eng. Hall.....	9:50-10:45	5	16
Sub-fresh.....	Ag. and Wm. Alg..	Math. 1a...	Mr. Reece........	8 College Hall...	9:50-10:45	5	14
Sub-fresh.....	Ag. and Wm. Alg..	Math. 1a...	Mr. Reece........	8 College Hall...	10:45-11:40	5	17
Freshmen....	Eng. Alg.........	Math. 1f ...	Mr. Reece........	103 Ag. Hall......	2:30- 3:25	5	16
Freshmen....	Eng. Alg.........	Math. 1f....	Mr. Nye..........	101 Ag. Hall......	9:50-10:45	5	18
Freshmen....	Eng. Alg.........	Math. 1f....	Mr. Nye..........	109 Eng. Hall.....	12:40- 1:35	5	21
Freshmen....	Eng. Alg.........	Math. 1f....	Mr. Emmons......	2 College Hall ..	9:50-10:45	5	21
Freshmen....	Eng. Alg.........	Math. 1f....	Mr. Hopphan.....	2 College Hall ..	8:55- 9:50	5	20
Freshmen....	Eng. Alg.........	Math. 1f....	Mr. Hopphan.....	100 Ag. Hall......	12:40- 1:35	5	20
Freshmen....	Eng. Alg.........	Math. 1f....	Mr. Snepp........	102 Ag. Hall......	9:50-10:45	5	18
Freshmen....	Eng. Alg.........	Math. 1f....	Mr. Snepp........	102 Ag. Hall......	12:40- 1:35	5	21
Freshmen....	Ag. and Wm. Alg..	Math. 2b...	Mr. Snepp........	102 Ag. Hall......	10:45-11:40	5	18
Freshmen....	Ag. and Wm. Alg..	Math. 2b...	Mr. Hopphan.....	109 Eng. Hall.....	1:35- 2:30	5	14
Freshmen.....	Ag. and Wm. Alg..	Math. 2b...	Mr. Beighle.......	2 College Hall...	1:35- 2:30	5	16
Freshmen....	Ag. and Wm. Alg..	Math. 2b...	Mr. Beighle.......	2 College Hall...	2:30- 3:25	5	20
Freshmen....	Ag. and Wm. Alg..	Math. 2b...	Mr. Robertson....	100 Ag. Hall......	9:50-10:45	5	19
Freshmen....	Ag. and Wm. Alg..	Math. 2b...	Mr. Robertson....	213 Eng. Hall.....	10:45-11:40	5	17
Freshmen....	Ag. and Wm. Alg..	Math. 2b...	Mr. Johnson......	8 College Hall...	8:00- 8:55	5	19
Freshmen....	Ag. and Wm. Alg..	Math. 2b...	Mr. Johnson......	103 Ag. Hall......	9:50-10:45	5	21
Freshmen....	Ag. and Wm. Alg..	Math. 2b...	Mr. Johnson	103 Ag. Hall......	10:45-11:40	5	18
Freshmen....	Ag. and Wm. Alg..	Math. 2b. .	Mr. Emmons.... .	100 Ag. Hall......	8:00- 8:55	5	18
Freshmen....	Ag. and Wm. Alg..	Math. 2b...	Mr. Crowe........	100 Ag. Hall......	1:35- 2:30	5	16
Freshmen....	Ag. and Wm. Alg..	Math. 2b...	Mr. Crowe........	100 Ag. Hall......	2:30- 3:25	5	19
Sophomores...	Calculus..........	Math. 6a...	Mr. Crowe........	302 Eng. Hall.....	10:45-11:40	5	20
Sophomores...	Calculus..........	Math. 6a...	Mr. Emmons......	2 Ch. Hall......	10:45-11:40	5	21
Sophomores...	Calculus..........	Math. 6a...	Mr. Emmons......	2 Ch. Hall......	12:40- 1:35	5	19
Sophomores...	Calculus..........	Math. 6a...	Mr. Johnson......	8 Ch. Hall......	12:40- 1:35	5	20
Sophomores...	Calculus..........	Math. 6a...	Mr. Robertson....	103 Ag. Hall......	12:40- 1:35	5	19
Sophomores...	Calculus..........	Math. 6a...	Mr. Beighle.......	301 Eng. Hall.....	10:45-11:40	5	19

The fact that there is such a disparity in the amount of class room work in the several terms greatly complicates the problem of providing instruction.

During the year the department gave 383 special examinations including 133 in entrance subjects.

Respectfully submitted,
WARREN BABCOCK,
Professor of Mathematics.

East Lansing, Mich., June 30, 1911.

REPORT OF THE DEPARTMENT OF BOTANY.

President J. L. Snyder:

I have the honor to submit herewith my report as Professor of Botany for the year ending June 30, 1911.

The botanical staff consists, at present, of the following persons: Professor, Ernst A. Bessey, Assistant Professor, Richard de Zeeuw, Instructors, Rose M. Taylor, Bertha F. Thompson, Ruth F. Allen. In addition to these the Research Assistant in Plant Physiology and the Research Assistant in Plant Pathology of the Experiment Station, respectively William H. Brown and George H. Coons, devote one-fourth of their time to instruction in the botanical department in their respective subjects.

The number of students enrolled in the department is as follows: Fall term, 356; winter term, 384; spring term, 404; total 1,144 students, of whom 1,021 were enrolled for required and 123 for elective work. In addition to these, 46 short course students took the course on fruit diseases, making a grand total enrollment of 1,190.

The new part of the building, which was occupied with temporary tables during the spring term last year, was used regularly this year. Freshman and sophomore classes occupied rooms 14, 15 and 17, while rooms 14 and 16 were also used for some of the more advanced classes. In the old building, room 8 was used for freshmen and sophomores, as well as for advanced classes. The lecture room was used only for lectures, not as a laboratory, being totally unsuited for the latter. This spring, room 16 in the new part had to be given up to the Experiment Station botanists as the room previously occupied by them was too small. The north half of room 6 in the old building was partitioned off as an office for the professor, the room formerly occupied for this purpose having been too small for years to accommodate books, laboratory table, etc. This room has been given to the assistant professor.

During the year the whole building was piped for gas while the electric lighting has been made more modern.

The laboratory desks and chairs ordered last spring were received and installed during the winter. Those tables used for work with microscopes were equipped with inverted Welsbach lamps. All tables were provided with Bunsen burners or with other gas connections. The tables in the physiological laboratory were provided with both water and gas.

During the year a number of compound microscopes were purchased, so that, at present, there are three laboratories equipped with twenty-five compound microscopes each and one with twenty-four. During some periods of the day all four laboratories are in use. However, it does not seem probable that another large laboratory will have to be equipped for a year or two. The more advanced students, however, need to have a small laboratory equipped inasmuch as it is becoming more and more difficult to arrange free time when they can use the other laboratories.

The greenhouse, of which only the outer part was finished at the beginning of the year, has been completed. It has been provided with reinforced cement benches and a large cement tank for growing water plants.

In equipping the laboratories, much remains still to be done in the way of procuring apparatus for the physiological and pathological laboratories.

The herbarium room is crowded to overflowing and it will be necessary this summer to provide for an extension of the herbarium into the adjoining room. The latter is, unfortunately, not fireproof but it is hoped that some day, this can be vaulted in and made fireproof in the same manner as was done for the present herbarium room. Several hundred plants have been added this past year. Plans are under way for the segregation of Michigan plants from others in order that the Michigan herbarium may be made more easily available, comprising as it does, one of the best, if not the best, collection of Michigan plants in existence.

The Botanical Garden has "marked time" since Dr. Beal's departure as my time has been chiefly occupied in teaching work and in getting the department under way. However, a weed garden has been provided, exhibiting the sixteen weeds mentioned in the Pure Seed Law as well as about fifty others common in Michigan. It is intended to extend this from time to time as weeds become better known. A garden of poisonous plants is planned with special reference to the course in poisonous plants given in connection with the veterinary course.

In the basement of the Botanical Building are several cords of tinder-dry logs, being specimens of trees accumulated by my predecessor while he taught the subjects of botany and forestry. It is highly desirable that these be disposed of as their presence is a menace to the safety of the building. Should they once catch on fire, it would be useless to attempt to save any part of the old building and unless the wind was favorable, to save the new building would be a difficult task. I call this to your attention in the hope that you may be able to assist the Forester to find a storage place other that that now occupied by them, for such of these specimens as have interest from the standpoint of forestry. If no such place can be found, I would recommend that I be permitted to remove them from the building on account of the danger incurred by allowing them to remain.

Respectfully submitted,

ERNST A. BESSEY,

Professor of Botany.

East Lansing, Mich., June 30th, 1911.

REPORT OF THE CHEMICAL DEPARTMENT.

President J. L. Snyder, Michigan Agricultural College:

Dear Sir:—I herewith submit the usual annual report of the work of the Chemical Department for the year 1910-1911:

Fall term, 1910.	No. students.	Total.
General chemistry:		
Engineering students (freshmen)	178	
Agricultural students (freshmen)	155	
Women (sophomores)	46	379
Organic chemistry:		
Agricultural students (soph. men)	120	120
Total	....	499

Winter Term, 1911.	No. students.	Total.
Mineralogy (freshmen engineers)	156	
Qualitative Analysis (agricultural men) (freshmen)	145	
Qualitative Analysis (women sophomores)	46	
Agricultural Chemistry (Jr. and Sn. Ags.)	63	
Forestry Chemistry (Sns)	12	
Advanced Engineering Chemistry (Sns.)	23	
Total	....	445

Spring Term, 1911.	No. students.	Total.
Engineering Chemistry (freshmen)	146	
Organic Chemistry (women sophomores)	46	
Animal Nutrition (Sn. agricultural students)	15	
Domestic Science Chemistry (Sn. women)	10	
Quantitative Analysis	11	
Total	....	228

The schedule printed above shows the amount of class and laboratory work done during the year together with the number of students who registered for the work.

In the required subjects the number of students is but little greater than we have usually had to handle during the college year. I found the freshmen class entering in the fall to be made up of the best pre-

pared men that have ever entered the department. This is doubtless due to the steady pressure brought to bear by the college to induce students to either complete their high school work before entering M. A. C. or to be at least as well grounded in English, mathematics and elementary science as are our graduates from Michigan high schools.

In the elective courses the class in Agricultural Chemistry was the largest ever assembled at this college. The number of juniors and seniors registering for this subject being 63,—an increase of 30 per cent. over any other class electing the subject. This increase in the number of students taking elective work necessitated the omission of our part of the usual course of lectures given to the special short course students during the winter term.

A class of 40 senior engineering students elected the subject of Advanced Engineering Chemistry for the winter term, but we were obliged on account of lack of space to accept but 24 of these men. Fortunately for our future outlook in this matter the Board in Dec., 1910, authorized the preparation of plans for a substantial addition to the present laboratory building. Accompanied by Architect E. A. Bowd I visited the laboratories at the University of Michigan and Illinois. Plans were then prepared and submitted to the Board which were accepted and an addition to the present laboratory building which will increase its available space nearly 50 per cent. is now under way. The completion of this building, which I have every reason to hope will be brought about by the opening of the fall term, 1911, provides such increase of both laboratory and lecture room space that the work of instruction will be much more easily accomplished.

It is perhaps worthy of note that the first part of the present Chemical Laboratory was built in the year 1871; the south wing was next added in 1881, and the east wing now under construction in 1911.

In closing I wish to acknowledge the hearty cooperation of my staff for the past year composed as follows:

H. S. Reed, Assistant Professor.
A. J. Clark, Assistant Professor.
W. H. Parker, Instructor.
M. L. Tower, Instructor.
C. M. Hargrave, Instructor.
H. M. Potter, Instructor.
E. A. Goodhue, Clerk and Stenographer.
Geo. Churchill, Caretaker.

Respectfully submitted,
FRANK S. KEDZIE,
Professor of Chemistry.

East Lansing, Mich., June 30th, 1911.

REPORT OF THE DEPARTMENT OF ENTOMOLOGY.

President J. L. Snyder:

Dear Sir:—Following is a brief report of the work of the Department of Entomology for the year ending June 30th, 1911.

Six regular courses in entomology have been given during the year, course V being given through the entire year. Besides this, two courses were given to short course students during the winter term. This in reality makes ten courses.

Trips were made to Hillsdale and to Hudson to address meetings held at the high schools in connection with the agricultural work of the schools.

The work of the year requires very little comment. Good-sized classes were registered in all of the courses, and little has occurred to break the even continuity of the work.

The force has remained the same. Miss Eugenia McDaniel devotes half her time to the college work and the writer gives a like amount. Dr. Geo. D. Shafer has very willingly responded in time of need, and helped out in emergencies, and Mr. P. W. Mason, a senior student-assistant helped out in the large laboratory sections.

A good deal of material has been collected and much has been bred for demonstration work and for the collection, although our force has been so regularly devoted to teaching that little material could be closed into the collection.

The year has passed pleasantly, the quarters are ample, and comfortable, and the work agreeable.

Respectfully submitted,
R. H. PETTIT,
Professor of Entomology.

East Lansing, Mich., June 30th, 1911.

REPORT OF THE DEPARTMENT OF ZOOLOGY AND PHYSIOLOGY.

To the President:

Sir:—I have the honor to submit the following report of the Department of Zoology and Physiology, and the General Museum, for the year ending June 30, 1911:

With minor exceptions, the teaching staff of the department has been the same as last year; namely, Assistant Professor Jesse J. Myers, and Instructors Benjamin B. Roseboom, Frederick A. Burt, and Harold S. Osler. Mr. J. L. Whitney, who was student-assistant in the spring of 1910, dropped out at the end of the year and was replaced in the fall by Robert J. Baldwin of the class of 1904. On the first of January,

however, Mr. Baldwin was transferred to Dean Shaw's office and in his place the department secured Mr. Oscar B. Park, a graduate of James Milikin University, Lincoln, Ill. Mr. Park was engaged only for six months and was released on June 30. Since the number of students and classes continues to increase it will be necessary to employ at least one additional instructor and perhaps two for the coming year.

As in former years, it is a pleasure to acknowledge the hearty co-operation and efficient work of the entire corps of instructors, and this despite a larger number of teaching hours and more constant demand upon the instructor than in most departments of the college. Aside from the regular recitation and lecture work, all classes have a large amount of laboratory work which involves careful preparation, often weeks in advance, so that instructors are kept busy at all times in collecting and preparing this material. If by any chance one should have leisure, there is always an abundance of work in connection with the general museum which of late years has been necessarily more or less neglected because of the pressure of class work. The following table shows the number of classes, section, students, and instructors each term in the year:

Schedule of Classes for 1910-1911.

Term.	Subject.	Course.	Class.	No. students.	No. sections.	Instructors.
Fall	Geol. 1a	Agr., For	Soph	114	4	Barrows, Burt, Osler.
Fall	Geol. 2a	Agr., For	Jun.-Sen	30	2	Barrows, Burt.
Fall	Anat. 1b	Home Econ	Soph	45	2	Myers, Roseboom.
Fall	Phys. Geog. 1a	Agr., For., Vet	Sub.-Fresh	60	4	Myers, Osler, Baldwin.
Fall	Phys. Geog. 1b	Home Econ	Sub.-Fresh	16	2	Myers.
Winter	Zool. 2a	Agr., For	Jun.-Sen	25	2	Barrows, Myers, Roseboom, Burt.
Winter	Zool. 2b	Home Econ	Jun.-Sen	4	1	
Winter	Anatomy 1a	Agr., For	Soph	119	4	Myers, Roseboom, Osler, Park, Burt.
Winter	Physiology 2	Veterinary	Soph	5	1	Myers.
Winter	Geol. 1b	Home Econ	Soph	45	2	Barrows, Burt, Osler.
Spring	Zoology 1a	Agr., For	Fresh	148	6	Barrows, Myers, Roseboom, Burt, Osler, Park.
Spring	Zoology 1b	Home Econ	Fresh	91	4	
Spring	Zoology 3a	Agr., For	Jun.-Sen	37	3	Barrows, Myers, Osler.
Spring	Zoology 3b	Home Econ	Jun.-Sen	15	2	Barrows, Myers, Osler.
Spring	Physiology 2	Veterinary	Soph	5	1	Myers.
Totals				759	40	

The foregoing statement of classes is very similar to that given last year, but one new class has been added; namely, physiology 2, made necessary by the opening of the veterinary department and the enrollment of a small class in veterinary physiology. This course will consist of three consecutive terms and will be given with the aid of all proper apparatus and material. In connection with the new course of

study for the agricultural and forestry departments, some changes will be made in the work of this division, but they do not become operative until next year. A new elective in zoology will be offered, zoology 4 (vertebrate zoology), and an advanced course in human physiology will be instituted for the home economics department.

Little has been done by the department during the past year in the way of College Extension work, for the reason that from the opening of college in September until its close in June every member of the department is fully occupied with class work. The large increase in the number of our graduates, many of whom become teachers, and the general development of interest in nature study throughout the state brings to the department hundreds of inquiries each year in regard to text books, laboratory methods, specimens for class use, and inquiries as to reference books and other means for the determination of specimens. We also receive yearly a large number of samples of sands, clays, marls, ores, building stones, etc., with requests for examination, analysis, or advice as to development and use. Some of these requests are necessarily referred to the State Geologist, but in most cases they can be attended to in our own department. The demand from teachers for some guide in the study of birds has been general and insistent for several years past, and hence at the request of the Superintendent of Public Instruction, Hon. Luther L. Wright, the writer prepared in January a little bulletin describing seventy-five common birds of the state which was issued in the spring as Bulletin Number 37 of the Department of Public Instruction and has just been republished as one section of the larger bulletin of the same department known as "Michigan Special Days." This paper consisted of thirty-five pages of printed matter with a few half-tones and two colored plates obtained from the National Committee of Audubon Societies. This little bulletin, distributed solely through the Department of Public Instruction, must not be confounded with the larger work on Michigan Birds which the writer has had in preparation for several years past and which has just been completed, but has not yet gone to the printer. This book, for it can hardly be described as a bulletin, consists of something over one thousand typewritten pages and comprises full descriptions of about three hundred and thirty species of Michigan birds, together with critical notes on all other species which have been attributed to the state, the whole systematically arranged and provided with artificial keys for the determination of specimens, and preceded by a general introduction describing the topography and climate of the state in so far as it influences bird life and bird distribution. In addition the volume contains seventy full page plates and one hundred and fifty-two text figures. It is hoped that the college can provide at once for its printing, in which case it can doubtless be issued soon after the appearance of the present report.

GENERAL MUSEUM.

The general museum was given somewhat extended mention in last year's report and little more need be said this year, since there have been few changes of importance. Numerous small but welcome accessions have been made, but the crowded condition of the main hall and the lack of time and assistance have prevented the arrangement and dis-

play of most of these. The Broas collection of Michigan birds and the Bullock collection of Chilian birds and mammals have excited much interest, but both collections should be better displayed, especially the Broas collection, of which less than one-quarter is now on exhibition. During the coming year it is intended to provide the entire zoological and mineralogical collections of the museum with printed labels of uniform size and appearance, a plan which will increase the attractiveness and efficiency of the museum very greatly. As stated in previous reports, one of the strongest needs of the department, and in my opinion of the college, is a new and spacious building which shall accommodate the entire natural history collections and at the same time provide lecture rooms, recitation rooms and laboratories for all the classes which fall to this department and which are now very inadequately provided for. With such a building our general museum might easily rank as the first in the state.

Respectfully submitted,
WALTER B. BARROWS,
Prof. of Zoology and Physiology, and
Curator of General Museum.

East Lansing, Mich., June 30, 1911.

REPORT OF THE DEPARTMENT OF ENGLISH AND MODERN LANGUAGES.

President J. L. Snyder:

Dear Sir:—In the Department of English and Modern Languages during the year 1910-1911 the enrollment of students was as follows:

	English.	German.	French.	Total.
Fall	1,498	136	39	1,673
Winter	1,491	179	35	1,705
Spring	1,085	138	28	1,251

The average enrollment per term has been 1,543 against 1,632 during the preceding year.

The average cost of instruction per student in the department during the year has been $7.55, or $.60 more than during the year 1909-1910.

The work of the department during the year has been done by one professor, one assistant professor, and ten instructors. Five of the instructors, Messrs. Mayne, Pyke, Penney, Fischer and VonTungeln, came to us at the beginning of the year, taking places made vacant by the resignation of Messrs. Sloat, Williamson, Wuebker, Stott and Fish. Four of the instructors who left us a year ago went to places paying them larger salaries than we paid them; one man almost doubling his salary. The fifth man went to a university to continue his graduate work. The average salary paid to instructors during the present year has been $825.00, or $40.00 more than during the year 1909-1910.

In view of the fact that five out of the twelve members of the department were new to the work, I feel that the department has had an unusually successful year. The friction caused during the preceding year by two or three drastic regulations relative to the work of students has entirely passed away. The students see that these regulations are for their own good, and without dissent have come into harmony with them. The result is that many students are acquiring an accuracy in writing, spelling, etc., which otherwise they would not have acquired.

Again this year certain work in letter writing was presented to a large number of short course men by the department. I believe that this is as profitable as any work that is done by the department. Perhaps it would be a good thing if more time could be given to this work and a larger number of the short course men could have an opportunity to profit by it.

For the first time our students have taken part in an inter-collegiate debate with Alma. On April 28th the two teams met at our armory and debated the question, "Resolved, That the Federal Government should retain ownership and control of all coal lands now in its possession, or hereafter acquired." Our team, made up of Messrs. G. H. Collingwood, G. H. Myers, and J. D. Fletcher, took the negative side of the question and were so fortunate as to secure a decision in their favor. Mr. Collingwood is a senior forestry student, Mr. Myers a sophomore engineering student, and Mr. Fletcher a sophomore forestry student. The judges were Messrs. Lawton T. Hemans, Mason; W. G. Coburn, Battle Creek, and E. C. Shields, Howell, and to them I wish to express the thanks of the college and the department for their willingness to serve us in this way. On May 6th, Messrs. C. C. Wilcox, G. H. Collingwood, and Isaac Margolis, debated the same question at Ypsilanti in our annual debate with the State Normal College. On this occasion our team defended the affirmative. The debate, however, was won by the Normal College team. In this debate Mr. Collingwood took the place of Mr. R. W. Powell, who because of illness was unable to occupy his place on the team. Mr. Margolis is an agricultural freshman and Mr. Wilcox a sophomore engineer.

These men secured their places on the team by going through a series of preliminary debates, which were participated in by a large number of students.

The annual oratorical contest was won by Mr. K. D. Van Wagenen. He consequently represented the college in the State Contest, and won second place on the contest, the highest place that has been won by this college for a number of years.

For the first time an oratorical contest, open only to freshmen, was held during the year. This was participated in by six contestants, first place being won by Mr. Robert J. McCarthy, and second place by Mr. Edwin J. Smith. Later in the year our third annual sophomore oration contest was held. In this contest nine men took part, first place being won by Mr. Wendt and second place by Mr. Smith. The Peace Oration Contest was participated in by six men, first place being won by Mr. E. C. Douglas, and second place by Mr. K. M. Klinger. Mr. Douglas therefore represented the college at the State Peace Contest, which was held at Hillsdale. This contest will be held with us next year.

That five so widely divergent subjects as literature, composition, public speaking, German, and French should be brought together under one department is an anomaly in an institution of his size. This no doubt was warranted in the early days of the college when its number of students was small and its number of instructors in proportion. In many institutions of this size each of these subjects is a department in itself. Such a division in this institution would perhaps be unwise. I feel, however, that the time has come for the modern languages to be made a separate department. The number of students studying German and French is such as to warrant this, and I am satisfied that the work in English, as well as the work in modern language, would be done better if each were entirely separate. Let me urge upon you the advisability of giving this matter careful attention and of inaugurating a new department of modern languages at an early date.

In view of the fact that the college is to be without an adequate auditorium for another four years, and in view of the further fact that the sentiment among the older alumni is such as to make improbable the tearing down of College Hall, I feel that this building should without delay receive the careful attention of yourself and of the State Board. In some way the southwest corner of the building should be repaired or should be rebuilt. We cannot afford to risk the lives of students, as perhaps we have been doing in holding classes in the building in its present condition. Perhaps it is perfectly safe, but at times this seems very doubtful. A new roof should be put on the building and its interior should be largely renewed. The putty in the window frames has been there so long that panes of glass are constantly falling out. The sinking of the building at the corner above mentioned has caused the window frames to be very loose, and in some instances not to fit in any way. The steam heating equipment was probably the first installed in the college. It was crude in the beginning, and with the passing of the years the pipes have become so rusty that it is almost a weekly occurrence in cold weather for the plumbers to drive out classes in order to install new pipes. The class rooms should be replastered, new blackboards should be installed, and modern class room furniture should take the place of the benches, some of which must date back almost to the beginning of the college. The stairways are very steep and should be replaced by easier stairways if the building is to continue to be used for recitation purposes. The treads are all but worn through in places, and new treads are an absolute necessity unless a new stairway is built. The chapel is in every way unattractive. I feel that it should be remodeled inside and should be fitted up with permanent opera chairs. Too much space is given to the platform. It would be easily possible to arrange it so that with semi-circular rows of seats it could seat fifty or sixty more than it now seats. The sanitary conveniences in the building are entirely inadequate and unsatisfactory and should be replaced by full modern equipment. In like manner the electric wiring of the building should be made to conform to modern standards.

Further, some arrangement should be made for chairs to be left constantly at the armory for use there. This department struggles continually against the lack of interest in public speaking and the vari-

ous contests that accompany it. Is it fair to ask the students when an oratorical contest or a debate is to be held to pay for the transportation of seats from one part of the campus to another, in order that the armory may be used? This has been the custom in the past. It would become entirely unnecessary if seats could be left at the armory for use at any time.

The department lacks entirely a place for satisfactory presentation of dramatic work of any kind and of course has no place for rehearsals in work of this sort. At a comparatively small expense it would be possible to install a permanent stage as an addition to the east end of the armory. This would take nothing from the present floor space of the armory, and along with seats left in the armory for use at any time, would go far toward providing an auditorium which would suffice until we can have the one which we unfortunately failed to secure this year.

I trust that these recommendations may receive attention, both for the sake of this department and for the good of the college at large.

I wish to thank you and the State Board for the constant encouragement and help given to the department during the year. In a technical institution it is not easy to maintain the interest of the students in work such as we present. If this department is to have success it must have at the same time such support as you have given it in the past and such as has been given to it by the faculty in general. I court for the department a continuation and an increase of interest from the other departments in the college.

Respectfully yours,

THOS. C. BLAISDELL,

Professor of English and Modern Languages.

East Lansing, Mich., June 30, 1911.

REPORT OF THE DEPARTMENT OF HISTORY AND ECONOMICS.

President J. L. Snyder:

Sir:—I have the honor of submitting the following report concerning the work of the department for the year 1910-11:

The total number of enrollments in the department for the year equalled 1,798, distributed as follows:

By terms, fall, 498; winter, 704; spring, 596.

By classes, sub-freshmen, 138; freshmen, 755; sophomores, 379; juniors, 301 and seniors, 192.

By subjects, History, 894; Economics, 731, and Political Science, 133.

The total number of hours taught during the year by members of the department were 2,904, divided among the three terms as follows:

Fall term, 871; winter term, 1,032; spring term, 1,001.

By subjects the number of recitation hours during the year equalled, History, 1,625; Economics, 1,309; Political Science, 190.

The distribution of class work to the various members of the department, together with the nature of the work performed by each, may be gathered from the subjoined table.

Teacher.	Term.	Subject.	Hours per week.	Students.	Number of students.
Mr. Hedrick	Fall	Economics 4a	7	Junior and Senior Agr., H. E., Forestry	39
Mr. Hedrick	Fall	Economics 4a	7	Junior and Senior, Agr., H. E., Forestry	63
Mr. Hedrick	Winter	Economics 5a	5	Junior and Senior, Agr., H. E., Forestry	30
Mr. Hedrick	Winter	Economics 5a	5	Junior and Senior, Agr., H. E., Forestry	28
Mr. Hedrick	Winter	Economics 1a	1	Agr., Sub.-Freshmen	60
Mr. Hedrick	Spring	Economics 7	5	Senior and Junior, Agr., H. E., Forestry	28
Mr. Hedrick	Spring	Economics 7	5	Junior and Senior, Agr., H. E., Forestry	29
Mr. Hedrick	Spring	Economics 2	2	Soph., Agr.	38
Mr. Ryder	Fall	Pol. Science 1a	5	Soph., Engineers	45
Mr. Ryder	Fall	History 4	5	Seniors and Juniors, Agr., H. E., Forestry	47
Mr. Ryder	Fall	History 4	5	Seniors and Juniors, Agr., H. E., Forestry	23
Mr. Ryder	Winter	Pol. Science 1a	5	Seniors and Juniors, Agr., H. E., Forestry	61
Mr. Ryder	Winter	History 5	5	Seniors and Juniors, Agr., H. E., Forestry	25
Mr. Ryder	Winter	History 5	5	Seniors and Juniors, Agr., H. E., Forestry	46
Mr. Ryder	Spring	Economics 6	5	Seniors and Juniors, Agr., H. E., Forestry	34
Mr. Ryder	Spring	Economics 6	5	Seniors and Juniors, Agr, H. E., Forestry	43
Mr. Ryder	Spring	Economics 2	2	Soph., Agr. and Forestry	33
Mr. Ryder	Spring	Economics 2	2	Soph., Agr. and Forestry	38
Mrs. Hendrick	Fall	History 1	3	Fresh., Ags. and H. E.	24
Mrs. Hendrick	Fall	History 1	3	Fresh., Ags. and H. E.	24
Mrs. Hendrick	Fall	History 1	3	Fresh., Agr., and H. E.	43
Mrs. Hendrick	Fall	Pol. Science 1a	5	Soph., Engineer	27
Mrs. Hendrick	Winter	History 3	5	Fresh., Agr.	27
Mrs. Hendrick	Winter	History 2	5	Fresh., H. E.	27
Mrs. Hendrick	Winter	History 3	5	Fresh., Agr.	40
Mrs. Hendrick	Winter	History 2	5	Fresh., H. E.	33
Mrs. Hendrick	Spring	History 3	5	Fresh., Engineer	31
Mrs. Hendrick	Spring	History 3	5	Fresh., Engineer	22
Mrs. Hendrick	Spring	History 3	5	Fresh., H. E.	22
Mr. Stevens	Fall	History 1	3	Fresh., Agr.	32

Teacher.	Term.	Subject.	Hours per week.	Students.	Number of students.
Mr. Stevens	Fall	History 1	3	Fresh., Agr	23
Mr. Stevens	Fall	History 1	3	Fresh., Agr	26
Mr. Stevens	Fall	History 1	3	Fresh. Agr	26
Mr. Stevens	Fall	Economics 1	3	Sub.-Fresh., H. E	17
Mr. Stevens	Winter	Economics 5a	5	Junior and Senior, Ags., H. E., Forestry	30
Mr. Stevens	Winter	Economics 4b	5	Soph. Engineer	44
Mr. Stevens	Winter	Economics 4b	5	Soph., Engineer	19
Mr. Stevens	Spring	Economics 5b	5	Soph., Engineer	23
Mr. Stevens	Spring	Economics 5b	5	Soph., Engineer	18
Mr. Stevens	Spring	Economics 2b	3	Soph., H. E	24
Mr. Stevens	Spring	Economics 2b	3	Soph., H. E	21
Miss Emery	Fall	History 2b	3	Fresh., Agr. and H. E	19
Miss Emery	Fall	History 2b	3	Fresh., Agr. and H. E	17
Miss Emery	Fall	History 2b	3	Fresh., Agr. and H. E	20
Miss Emery	Winter	History 3	5	Fresh., Agr. and H. E	42
Miss Emery	Winter	History 3	5	Fresh., Agr. and H. E	31
Miss Emery	Winter	History 3	5	Fresh., Agr. and H. E	19
Miss Emery	Winter	History 3	5	Fresh., Agr. and H. E	29
Miss Emery	Spring	History 3	5	Fresh., Engineer	26
Miss Emery	Spring	History 2	5	Fresh., H. E	32
Miss Emery	Spring	History 3	5	Fresh., Engineer	19
Miss Emery	Spring	History 2	5	Fresh., Engineer	18
Mr. Gillespie	Winter	History 1	5	Fresh., Engineer	38
Mr. Gillespie	Winter	History 1	5	Fresh., Engineer	35
Mr. Gillespie	Winter	Economics 4b	5	Soph., Engineer	33
Mr. McLean	Spring	Economics 5b	5	Soph., Engineer	18
Mr. McLean	Spring	Economics 5b	5	Soph., Engineer	20
Mr. McLean	Spring	Economics 1b	2	Sub.-Fresh., Agr	27
Mr. McLean	Spring	Economics 2	2	Soph., Agr	34

The curriculum changes which have taken place in this department as a result of the faculty action of last winter in reducing the required number of credits which a student must have in order to graduate are entitled to our first consideration. The reduction referred to entailed an almost uniform diminution of the students class attendance from five recitation hours per day to four and it is the hope of the authorities that more thorough preparation of lessons may now be made by students, on account of the less number of subjects that are required. The curtailment of the college curriculum naturally could not take place without a reduction of the number of credits in the subjects presented by the different departments and the offerings of history, economics and political science in various college courses were altered as follows: In the agricultural and forestry courses the work offered by this department was reduced from 43 possible credits to 42. In the engineering course a reduction from 25 possible credits to 14 possible credits was made, while in the home economics course the number of possible credits was increased from 46 to 48.

In the elimination of credits which has been described, history was cut most severely with the result that English history has been dropped entirely from all the courses of study. There was much justification for this aside from the mere matter of curriculum expedience, since English history is now being taught so widely in the different high schools of the state that its abandonment here does not leave the student unprepared for the advanced courses for which it was in former times a logical prerequisite. Commercial geography was also droppel from

the college curriculum as a part of the shrinkage process. On the other hand a three credit study in sociology was added to the required work in the home economics course, while an additional elective in United States history was inserted in the agricultural, home economics and forestry courses.

One of the results of these alterations which is of considerable importance to the department has been the contraction of the departmental teaching staff from six members to four. It was found that all of the eliminations which were made from the History and Economics studies comprised subjects which were given in the freshmen and subfreshmen years where classes are large and class sections numerous. Withdrawing subjects like these meant simply that duplicate teachers could be dispensed with and the curtailment just mentioned was the result. The increasing restriction of the work done by this department to the elective years where large classes can be handled, and, to fewer subjects, as a result of the eliminations which have been mentioned, will afford the opportunity for greater specialization by the members of the department—a desirable result in every way.

In connection with this matter of departmental efficiency I feel that not a little has been lost through the withdrawal at the end of last year of the customary allowances of departmental stationery with the names of all members of the department printed thereupon. Some of the departments of this college have a history as old as that of the college itself and one or two of them have reputations so widely extended that to have it shown upon letterheads that he is associated with such a department is no small addition to the pay of the not overly remunerated young instructors in these departments. The teachers in History and Economics during the past year have contributed from their own pockets the necessary amounts for purchasing departmental stationery upon which the names of all the members thereof appeared. This seems a rather unjust tax to levy, however, since much of this stationery is used wholly in connection with the college business. It seems desirable in every way that the old arrangement of department paper, varied according to the needs of the different departments, might be resumed.

The worth of every subject presented in a college course is naturally enhanced by having such an arrangement of conditions as will permit this subject to have the space in the college curriculum which its importance deserves. Two of the subjects in this department have now acquired for themselves situations which allow them to be presented fairly adequately and quite efficiently. These are Economics and American History. The first of these subjects runs throughout the entire college year in three of the college courses and furnishes no problems in adaption more serious to the teacher than those of selection. When it is remembered that not a few of our larger schools offer as many as sixty or seventy courses in this subject and that additional ones are constantly being developed, it will be seen that the problem at this place of choosing just the ones which should be given during three terms has no easy solution. The solution which was approved during the past year involved the study of economic resources during the first term, economic principles during the second and American industrial development during the third term.

This arrangement places a minimum of study upon abstract principles and a maximum upon the concrete in economics—an arrangement for which our students seem especially fitted through the prevalence of laboratory work here and the consequent familiarity that there is with the concrete.

The American History to which reference was made, when taught as it is here in conjunction with political science, may also be regarded as a subject which extends through all three terms although unfortunately the work of two of these terms must be taken during the same period of time. In the case of both subjects one teacher has charge of each subject continuously throughout the entire year and the departmental specialization whose benefits were mentioned earlier is well exemplified by these two instances.

In conclusion I wish to commend the efficiency and devotion of the various teachers in the department during the past year, the statistical statement of the efforts of whom appears in an earlier part of this report.

Yours respectfully,
WILBUR O. HEDRICK,
Professor of History and Economics.

East Lansing, Mich., June 30th, 1911.

REPORT OF THE LIBRARIAN.

President J. L. Snyder:

Dear Sir:—The following is the report on the library for the year ending June 30th, 1911.

There have been added to the library during the year twelve hundred thirteen bound volumes, of which five hundred eighty-six were purchased, two hundred nine were gifts, and four hundred eighteen came by binding. There have also been added five hundred fifty-six unbound volumes and pamphlets, all of which were duly acknowledged when received, provided the donor was known.

For bound volumes we are indebted as follows:

Aaron, Dr. Chas. D., 1.
American Sheep Breeders' Ass'n., 1.
American Shropshire Sheep Breeders' Ass'n., 4.
Aberdeen Angus Ass'n., 3.
American Society Veterinary Medicine, Proc., 6.
American Guernsey Cattle Club, 1.
Beal, Dr. W. J., 1.
Baker, R. S., 20.
Bureau Amer. Ry. Economics, 2.
Cochrane Pub. Co., 1.
Colorado, Flora of, 1.
DeBar, J., 1.
Delaware, 1.
Dryden, J. F., 1.
Dennison, C. S., 1.
Homan, J. A., 1.
Illinois, 1.
Iowa, Horticultural Society, 1.
Iowa, Agriculture, 1.
Japan, 1.
Kansas, Horticultural Society, 3.
Lyman, Dr. R. P., 1.
Massachusetts, 2.
Michigan, 83.
Missouri Botanical Gardens, 1.
Missouri Horticultural Society, 1.
Myers, W. S., 1.

New York, Education Dept., 1.
New Jersey, 3.
National Conference Charities and Corrections, 1.
National Ass'n. Public Health, 1.
N. Carolina, Agriculture, 1.
Piper, Mr. H. P., 6.
Rand, McNally & Co., 1.
Raymond, Geo. L., 1.
Rhode Island, 4.
Stark, Hon. G. M., 1.
Smithsonian Institution, 10.
United States,
Agriculture Dept., 6.
Agriculture Dept. Library, 4.
United States,
Interstate Commerce Commission, 1.
Civil Service Commission, 2.
Census Bureau, 8.
Labor Bureau, 2.
Library of Congress, 4.
Land Office, 1.
Navy Dept., 1.
National Museum, 1.
Treasury Dept., 1.
United States Brewers' Ass'n., 3.
United Charities, Chicago, 1.
Vermont, Agriculture, 1.
Wilson & McMaster, Notes on Mechanical drawing.

(The publications sent us by the Supt. of Documents, now in storage in the agricultural building, are not included in the above list.)

In the reading room may be found nearly five hundred periodicals, foreign and American, either purchased by the College, or sent by publishers as donations or exchanges. The titles of donations and exchanges are as follows:

Adrian Times.
Agricultural Gazette of N. S. Wales.
Agricultural Advertising.
Agricultural Student's Gazette, England.
Allegan Gazette.
American Cheesemaker.
American Economist.
American Missionary.
American Poultry Advocate.
American Sheepbreeder.
American Sugar Industry.
American Swineherd.
American Thresherman.
Arboriculture.
Agricultural Ledger, Calcutta, India.
Ann Arbor Argus.
Armada Graphic.
Arrow, The.
Australiasian.
Bay City Times.
Battle Creek Journal.
Bear Lake Beacon.
Belding Banner.
Berkshire World and Corn Belt Stockman.
Better Fruit.
Bulletin of the College of Agriculture, Tokio.
Chicago Live Stock World.
Canadian Farm.
Church Helper.
Canadian Horticulturist.
Cattle Specialist.
Chicago Daily Farmers' and Drovers' Journal.
Chicago Packer.
Christian Herald.
Columbia University Quarterly.
Congressional Record.
Daily Drovers' Journal and Stockman, Omaha.
Dakota Farmer.
Electrical Times.
Economic Bulletin.
Farm and Fireside.
Farm and Home.
Farm Life.
Farm News.
Farm World.

Farmers' Advocate.
Farmers' Guide.
Farmers' Voice.
Florists' Exchange.
Garden.
Garden Magazine.
Gleaner.
Gleanings in Bee Culture.
Good Health.
Grand Ledge Independent.
Hawaiian Forester.
Hillsdale Leader.
Hillsdale Standard.
Hoard's Dairyman.
Holstein-Friesian Register.
Holstein-Friesian World.
Home and Farm.
Homestead.
Horseshoers' Journal.
Horse World.
Improvement Era.
India, Dept. of Agriculture, Report.
    Memoirs (Botanical series.) Research Inst., Pusa.
    Memoirs (Entomological series).
    Agri. Journal of India Series, Pusa.
Indian's Friend.
Indiana Farmer.
Illuminating Engineer.
Iowa Horticulture.
Journal of the College of Agriculture, Tokio.
Jamaica Dept. of Agriculture, Bulletin.
Jenner (now Lister) Institute of Preventive Medicine.
Jersey Bulletin.
Johns Hopkins Univ. Circulars.
Journal of Agriculture, Australia.
Journal of Agriculture, Victoria.
Journal of the Board of Agri. and Fisheries, England.
Kalamazoo Telegraph.
Kansas Farmer.
Kimball's Dairy Farmer.
Labor Digest.
Lawton Leader.
Lewiston Journal.
Live Stock Journal.
Live Stock Report.
Mark Lane Express.
Michigan Dairy Farmer.
Michigan Farmer.
Michigan Mirror.
Michigan Presbyterian.
Midland Farmer.
Milchwirtschaftliches Centralblatt.
Moderator-Topics.
National Stockman and Farmer.
N. Y. Meteorology. (Draper's Hourly readings).
N. Y. Produce Review.
Ohio Farmer.
Official Gazette, U. S. Patent Office.
Orange Judd Farmer.
Oregon Agriculturist.
Owosso Press American.
Poultry Keeper.
Practical Dairyman.
Park and Cemetery.
Phillipine Agrl. Review.
Practical Farmer.
Publicity Magazine.
Records of the Australian Museum.
Redman.
Reliable Poultry Journal.
Republic, Rockefeller Institute for Medical Research, Studies.
Rural Advocate.
Rural New Yorker.
Southern Farm Magazine.
Saginaw Evening News.
State Journal, Lansing.
Southern Cultivator.
Special Crops.
Successful Farming.
Twentieth Century Magazine.
Tuscola County Advertiser.
Western Society of Engineers, Journal.
Wallace Farmer.
Washington Acad. of Sciences, Proceedings.
Weather Review.
Wilson Bulletin.
Writer.

The publications received by the M. A. C. Record are placed on file in the reading room, and the catalogues of the leading educational institutions of the country are received and filed in the office of the librarian.

The bulletins of the various state experiment stations, and the publications of the United States Dept. of Agriculture are also received and filed, as are also the card indexes which cover them.

The number of books taken from the library during the year is seven thousand ninety-one. No attempt is made to record books used in the library. Fines to the amount of $31.44 have been collected, and placed to the credit of the library.

During the year the room in the agricultural building which the Dean of Agriculture kindly set apart for our use was made available and we were able to remove our books from the engineering building, and place them on shelves, where they are now accessible. We take occasion to express our appreciation of Dean Bissell's kindness is so long allowing us to use a room which he needed for class work, and to Dean Shaw for making it possible for us to return this room to the engineering department. It seems unnecessary to speak of our crowded condition. Everyone understands the disadvantage under which we of the library are obliged to work, and we can only hope that sometime the situation may be relieved.

At the close of the college year our assistant, Miss Agnes Crumb, resigned. Miss Crumb has been a most efficient and agreeable helper in the library, and we regret her departure. She will be succeeded by Miss Elizabeth Palm of this years' graduating class, whom we feel that every one connected with the college will be glad to welcome.

To the library of the Experiment Station have been added eleven hundred ninety-one volumes, of which twenty-seven were purchased, all others from binding. The college library now numbers thirty thousand thirty-seven volumes, and the experiment station library contains four thousand ninety-one volumes. Total in both libraries, thirty-four thousand two hundred twenty-eight volumes. In this total are included all books belonging to departments so far as they have been catalogued.

The library hours have remained unchanged during the year, and for Mr. F. C. Kaden, who has been in charge on Saturday nights and Sundays, we have only words of commendation.

Respectfully submitted,

LINDA E. LANDON,

Librarian.

East Lansing, Mich., June 30th, 1911.

REPORT OF THE MILITARY DEPARTMENT.

The President, Michigan Agricultural College:

Sir:—I have the honor to submit the following report of the Military Department for the year ending June 30, 1911:

The instruction given during the year was practically the same as during the previous year, with a few exceptions hereinafter noted.

At the beginning of the fall term the instruction of the new cadets was conducted under the immediate supervision of myself and my assistant. A lieutenant of each company was in charge of the new men of his company, assisted by a number of acting corporals of that company (sophomores and five-year freshmen). An attempt was made to have each acting corporal instruct the same squad of four men during the entire period. In this way we were able to advance the men showing greatest aptitude and attention, and the corporal's ability as an instructor could be watched and rewarded. The instruction was more systematic than formerly and good results were obtained. Towards the close of the period the acting corporals who had shown the greatest ability were given permanent appointment and placed in line for promotion.

For theoretical instruction during the second half of the fall term and first half of the winter term the sophomore class was divided into three sections. All non-commissioned officers were assigned to my section. The other two sections were instructed by Cadet Lieutenant Colonel E. W. Baldwin and Cadet Major N. Van Horne. Both young men accomplished very good results.

During the winter term each captain instructed the new men of his company as a regular class in Infantry Drill Regulations one hour per week as a part of the ordinary drill. Very good results were obtained. The captains seemed to appreciate the responsibility and the discipline was excellent.

During both the fall and winter terms some use was made of the pavilion in the Agricultural Building. The instruction here consisted mostly of calisthenics and was conducted by Cadet Major McKibbin, and Cadet Lieutenants Springer and Sheffield.

The office of Cadet Colonel was created January 17, and Cadet Major C. W. McKibbin promoted to the office. His services were most satisfactory. He displayed unusual executive ability.

The organization of the twelfth company ("M") of the cadet regiment was completed January 23d. The Corps now consists of a regiment of infantry of three battalions of four companies each, hospital corps and band.

The annual War Department inspection was made by Captain G. H. Jamerson, General Staff, U. S. Army, May 15. His report has not yet been received, but it is thought it will show the department in satisfactory condition. The strength of the Corps at date of inspection was 674, of whom 652 were present under arms and in complete uniform.

In the competitive drill following the inspection, Co. "H," Capt. G. C. Sheffield, was awarded first place, Co. "E," Capt. W. R. Walker, second, Co. "M," Capt. A. M. Berridge, third.

On May 24th the Corps was reviewed by Brig. Gen. P. L. Abbey, Michigan National Guard, accompanied by the brigade staff.

In connection with the memorial exercises on May 29th the Corps was reviewed by Governor Chase S. Osborn, who expressed himself as well pleased with the appearance of the Corps. At the conclusion of the memorial services a tablet commemorating the students of the college who enlisted in 1861 for service in the Civil War was unveiled on the west wall of the armory building.

The Cadet Band under the direction of Prof. A. J. Clark continues in most satisfactory condition. An excellent spirit exists among its members. The band should receive every necessary support and encouragement.

I desire to acknowledge my appreciation of the support and assistance given me by my assistant, Sergt. P. J. Cross, U. S. Army, retired, and the cadet officers, particularly of the senior class with whom drill is optional. Their influence with the underclassmen is great. All field, staff, and company captains should be seniors whenever practicable.

Both indoor and outdoor instruction is greatly hampered by lack of space and it is hoped that some means to remedy this condition can soon be found. The rifles with which the Corps is armed are obsolete and should be condemned and disposed of. The last batch of 400 received from the State have seen hard service and many of them are in poor shape. The rifles get out of order easily and are not suited to our use.

Respectfully submitted,

G. M. HOLLEY,

1st Lieut., 11th U. S. Infantry,

Professor of Military Science and Tactics.

East Lansing, Mich., June 30th, 1911.

REPORT OF THE DEPARTMENT OF METEOROLOGY.

President J. L. Snyder:

Dear Sir:—Eighty-seven students enrolled during the fall term of 1910, in the course in meteorology, which was offered for the first time since the death of Dr. Kedzie. The subject was given as an elective study for juniors and seniors in the agricultural and forestry courses.

While it was gratifying to have so many students elect the subject, and this large number was inspiring in the lecture room, yet it was impossible to do the best work with so large a number in the laboratory. The class was divided into sections and still the sections were much too large to give each student the personal instruction and help that I had planned.

However each student performed the required laboratory work which consisted in observing and recording all the atmospheric conditions for one month, constructing weather maps, experimenting with meteorological instruments and studying the moisture and impurity content of the atmosphere.

Thirty-two lectures were given on the subject of meteorology and each student spent 52 hours in laboratory work.

Very Respectfully,

DEWEY A. SEELEY,

Instructor in Meteorology.

East Lansing, Mich., June 30th, 1911.

METEOROLOGICAL TABLES.

Meteorological observations for the month of January, 1910, at Agricultural College. East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.
1	38	16	27	.20	Cloudy.
2	36	22	29	.40	Partly cloudy.
3	22	4	13	.20	Partly cloudy.
4	16	5	10	0	Partly cloudy.
5	33	9	21	0	Partly cloudy.
6	18	14	16	0	Partly cloudy.
7	15	6	10	0	Partly cloudy.
8	26	4	15	.10	Partly cloudy.
9	25	15	20	0	Partly cloudy.
10	22	3	12	0	Clear.
11	30	17	24	0	Partly cloudy.
12	33	21	27	0	Partly cloudy.
13	30	23	26	.20	Cloudy.
14	27	20	24	.70	Clear.
15	27	21	24	0	Clear.
16	28	22	25	0	Partly cloudy.
17	35	25	30	0	Cloudy.
18	40	28	34	.05	Partly cloudy.
19	35	20	28	0	Clear.
20	42	30	36	.06	Partly cloudy.
21	38	20	29	0	Clear.
22	29	15	22	.05	Partly cloudy.
23	28	22	25	0	Cloudy.
24	33	24	28	0	Clear.
25	30	10	20	0	Clear.
26	42	27	34	.06	Partly cloudy.
27	34	27	30	.07	Partly cloudy.
28	29	20	24	.03	Clear.
29	29	12	20	0	Partly cloudy.
30	28	22	25	.15	Partly cloudy.
31	24	6	15	.25	Clear.
Mean	29.7	17.1	23.4	Total. 2.52	

TEMPERATURE.—Highest, 42; date, 20, 26; lowest, 3; date, 10; greatest daily range, 24; date, 5; least daily range, 4; date, 6;

PRECIPITATION.—Total this month, 2.52; snowfall, 23.4; greatest precipitation in 24 hours, .70; date, 14; snow on the ground at end of month, 12 inches.

WIND.—Prevailing direction, west.

WEATHER.—Number of days, clear, 9; partly cloudy, 18; cloudy, 4; on which .01 inch, or more, of precipitation occurred, 14.

*From records of cooperative observer, Michigan Agricultural College.

(Signed), ANDREW J. PATTEN,
Cooperative observer, Weather Bureau.

Meteorological observations for the month of February, 1910, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.
1	31	6	18	0	Clear.
2	40	19	30	.20	Clear.
3	37	23	30	.20	Clear.
4	32	18	25	0	Clear.
5	27	12	20	0	Partly cloudy.
6	13	0	6	0	Partly cloudy.
7	28	1	14	0	Partly cloudy.
8	34	22	28	.50	Partly cloudy.
9	35	20	28	.50	Partly cloudy.
10	26	6	16	.05	Partly cloudy.
11	26	12	19	0	Partly cloudy.
12	27	18	22	.15	Partly cloudy.
13	27	18	22	0	Partly cloudy.
14	35	15	25	0	Partly cloudy.
15	44	28	36	.40	Cloudy.
16	45	16	30	0	Cloudy.
17	17	9	13	0	Cloudy.
18	19	7	13	0	Partly cloudy.
19	27	8	18	0	Partly cloudy.
20	40	16	28	.30	Partly cloudy.
21	32	18	25	0	Partly cloudy.
22	26	8	17	0	Clear.
23	24	0	12	0	Partly cloudy.
24	17	0	8	0	Partly cloudy.
25	22	2	12	0	Partly cloudy.
26	39	17	28	.20	Cloudy.
27	38	30	34	.15	Cloudy.
28	40	29	34	0	Partly cloudy.
Mean	30.3	13.5	21.9	Total. 2.65	

TEMPERATURE.—Highest, 45; date, 16; lowest, 0; date, 6, 23, 24; greatest daily range, 29; date, 16; least daily range, 8; date, 17, 27.

PRECIPITATION.—Total this month, 2.65; snowfall, 4.0 inches; greatest precipitation in 24 hours, .50; date, 8 and 9; snow on the ground at end of month, 3.0.

WIND.—Prevailing direction, west.

WEATHER.—Number of days, clear, 5; partly cloudy, 18; cloudy, 5; on which .01 inch, or more, of precipitation occurred, 10.

*From records of cooperative observer, Michigan Agricultural College.

(Signed), ANDREW J. PATTEN,
Cooperative observer, Weather Bureau.

Meteorological observations for the month of March, 1910, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.)			Precipitation. (In inches and hundredths.)	Character of day.
	Maximum.	Minimum.	Mean.		
1	44	31	38	.10	Partly cloudy.
2	42	30	36	0	Clear.
3	48	28	38	0	Clear.
4	58	33	46	0	Clear.
5	54	34	44	0	Clear.
6	65	37	51	0	Clear.
7	39	22	30	0	Partly cloudy.
8	40	24	32	0	Partly cloudy.
9	38	23	30	0	Clear.
10	41	21	31	0	Clear.
11	39	25	32	0	Partly cloudy.
12	50	26	38	0	Clear.
13	47	27	37	0	Partly cloudy.
14	30	20	25	0	Partly cloudy.
15	41	15	28	0	Partly cloudy.
16	48	32	40	0	Clear.
17	38	26	32	0	Clear.
18	62	37	44	0	Clear.
19	70	38	54	0	Clear.
20	58	42	50	.20	Clear.
21	57	28	42	0	Clear.
22	68	28	48	0	Clear.
23	63	32	48	0	Clear.
24	82	43	62	0	Clear.
25	66	47	56	0	Clear.
26	66	37	52	0	Clear.
27	65	44	54	0	Clear.
28	78	49	64	0	Clear.
29	75	54	64	0	Clear.
30	71	54	62	.10	Partly cloudy.
31	65	40	52	0	Partly cloudy.
Mean	55.2	32.8	44.0	Total. .40	

TEMPERATURE.—Highest, 82; date, 24; lowest, 15; date, 15; greatest daily range, 40; date, 22; least daily range, 10; date, 14.
PRECIPITATION.—Total this month, .40; snowfall, 1.00; greatest precipitation in 24 hours, .20; date, 20; snow on the ground at end of month, 0.
WIND.—Prevailing direction, south.
WEATHER.—Number of days, clear, 22; partly cloudy, 9; cloudy, 0; on which .01 inch, or more, of precipitation occurred, 3.
MISCELLANEOUS PHENOMENA (dates of).—Thunderstorms, 20.
*From records of cooperative observer, Michigan Agricultural College.

(Signed), ANDREW J. PATTEN,
Cooperative observer, Weather Bureau.

Meteorological observations for the month of April, 1910, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.
1	65	33	49	0	Clear.
2	62	37	50	0	Clear.
3	63	42	52	0	Partly cloudy.
4	71	53	62	.15	Cloudy.
5	75	56	66	0	Cloudy.
6	60	35	48	0	Cloudy.
7	50	30	40	0	Partly cloudy.
8	66	30	48	0	Clear.
9	69	43	56	0	Clear.
10	64	37	50	0	Clear.
11	70	37	54	0	Partly cloudy.
12	52	28	40	0	Clear.
13	66	29	48	0	Clear.
14	76	40	58	0	Clear.
15	74	51	62	.15	Cloudy.
16	65	55	60	.10	Cloudy.
17	64	37	50	.25	Cloudy.
18	50	41	46	.20	Partly cloudy.
19	48	39	44	.05	Cloudy.
20	42	37	40	.10	Cloudy.
21	70	37	54	0	Partly cloudy.
22	62	40	51	.05	Partly cloudy.
23	52	32	42	0	Partly cloudy.
24	45	30	38	.05	Cloudy.
25	42	30	36	.50	Cloudy.
26	42	36	39	.73	Cloudy.
27	54	35	44	.10	Partly cloudy.
28	51	35	43	0	Cloudy.
29	77	36	56	0	Cloudy.
30	72	36	54	.05	Cloudy.
Mean	60.6	37.8	49.2	Total. 2.48	

TEMPERATURE.—Highest, 77; date, 29; lowest, 28; date, 12; greatest daily range, 41; date, 29; least daily range, 5; date, 20.
PRECIPITATION.—Total this month, 2.48; snowfall, 0; greatest precipitation in 24 hours, .73; date, 26; snow on the ground at end of month, 0.
WIND.—Prevailing direction, south.
WEATHER.—Number of days, clear, 8; partly cloudy, 8; cloudy, 14.
*From records of cooperative observer, Michigan Agricultural College.

(Signed), ANDREW J. PATTEN,
Cooperative observer, Weather Bureau.

Meteorological observations for the month of May, 1910, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percent of sunshine.
1	61	46	54	.43	Partly cloudy.	53
2	55	39	47	1.25	Cloudy	0
3	52	34	43	0	Clear	66
4	54	31	42	0	Clear	100
5	57	29	43	0	Clear	100
6	63	32	48	0	Clear	100
7	63	37	50	T	Partly cloudy.	67
8	61	48	54	T	Cloudy	19
9	68	43	56	0	Partly cloudy.	63
10	68	39	54	0	Partly cloudy.	84
11	59	37	48	0	Clear	95
12	55	32	44	0	Clear	99
13	44	32	38	T	Cloudy	21
14	53	28	40	0	Clear	99
15	62	34	48	0	Clear	100
16	64	38	51	0	Cloudy	56
17	64	49	56	.45	Cloudy	30
18	67	48	58	0	Clear	100
19	76	48	62	0	Clear	100
20	72	55	64	.08	Partly cloudy.	55
21	80	50	65	.73	Clear	88
22	78	59	68	.14	Clear	79
23	70	48	59	.42	Cloudy	11
24	67	45	56	0	Clear	82
25	61	40	50	0	Partly cloudy.	78
26	60	36	48	T	Partly cloudy.	83
27	70	37	54	0	Clear	100
28	76	40	58	0	Clear	100
29	72	43	58	.34	Cloudy	45
30	47	36	42	.14	Cloudy	3
31	44	36	40	.15	Cloudy	1
Mean	62.7	40.3	51.5	Total. 4.13		

Atmospheric Pressure.—(Reduced to sea level; inches and hundredths.)—Mean, 30.02; highest, 30.48; date, 4; lowest 29.62; date, 23.

Temperature.—Highest, 80; date, 21; lowest, 28; date, 14; greatest daily range, 36; date, 28; least daily range, 8; date, 31.

Precipitation.—Total this month, 4.13; snowfall, 0; greatest precipitation in 24 hours, 1.25; date, 2; snow on the ground at end of month, 0.

Wind.—Prevailing direction, northwest; total movement, 4973 miles; average hourly velocity, 6.5; maximum velocity (for five minutes), 24 miles per hour, from southwest on 29.

Weather.—Number of days, clear, 15; partly cloudy, 7; cloudy, 9; on which .01 inch, or more, of precipitation occurred, 10.

Miscellaneous Phenomena (dates of).—Auroras, 0; halos: solar, 7, 19; lunar, 15, 16; hail, 0; sleet, 0; fog, 0; thunderstorms, 2, 21, 22; *Frost: light, 6, 12, 13; 15, heavy, 4, 5, 14; killing, 0.

Note.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing."

Form 1030, Met'l will be issued monthly by the local office, U. S. Weather Bureau, and mailed free of charge to those who make application for the same to the official in charge.

D. A. SEELEY,
Local forecaster, Weather Bureau.

Meteorological observations for the month of June, 1910, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percent of sunshine.
1	40	38	42	.18	Cloudy	3
2	49	37	43	.55	Cloudy	12
3	54	42	48	T	Cloudy	19
4	64	41	52	0	Partly cloudy	57
5	60	45	52	.13	Partly cloudy	19
6	57	43	50	24	Cloudy	9
7	71	42	56	0	Clear	98
8	73	41	57	0	Clear	99
9	74	50	62	0	Partly cloudy	74
10	74	48	61	0	Partly cloudy	82
11	66	49	58	T	Cloudy	36
12	75	47	61	0	Clear	84
13	83	48	66	0	Clear	100
14	84	57	70	0	Partly cloudy	78
15	88	54	71	T	Clear	97
16	87	58	72	0	Clear	100
17	86	58	72	0	Partly cloudy	84
18	92	67	80	0	Clear	86
19	91	58	74	0	Clear	100
20	90	61	76	0	Clear	100
21	89	63	76	0	Clear	98
22	91	58	74	0	Clear	90
23	93	62	78	.76	Partly cloudy	71
24	81	58	70	0	Clear	100
25	82	52	67	0	Clear	100
26	87	53	70	0	Clear	100
27	75	60	68	.09	Cloudy	82
28	83	54	68	0	Clear	100
29	92	59	76	0	Clear	98
30	95	61	78	0	Clear	97
Mean	77.7	52.1	64.9	Total. 1.95		

ATMOSPHERIC PRESSURE.—(Reduced to sea level; inches and hundredths.)—Mean, 29.98; highest, 30.21; date, 4; lowest, 29.57; date, 1.

TEMPERATURE.—Highest, 95; date, 30; lowest, 37,; date, 2; greatest daily range, 35; date, 13; least daily range, 8; date, 1.

PRECIPITATION.—Total this month, 1.95; snowfall, 0; greatest precipitation in 24 hours, .76; date, 23; snow on the ground at end of month, 0.

WIND.—Prevailing direction, northwest; total movement, 3035 miles; average hourly velocity, 4.2; maximum velocity (for five minutes), 27 miles per hour, from north on 23.

WEATHER.—Number of days, clear, 17; partly cloudy, 7; cloudy, 6; on which .01 inch, or more, of precipitation occurred, 6.

MISCELLANEOUS PHENOMENA (dates of.—Auroras, 0; halos: solar, 10; lunar, 0; hail, 6; sleet, 0; fog, 0; thunderstorms, 6, 14 23; *Frost: light, 0; heavy, 0; killing, 0.

NOTE.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurence of "killing."

DEWEY A. SEELEY,
Local forecaster, Weather Bureau.

Meteorological observations for the month of July, 1910, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percent of sunshine.
1	97	62	80	0	Clear	100
2	93	61	77	0	Partly cloudy	92
3	81	63	72	0	Partly cloudy	58
4	77	56	66	0	Clear	100
5	85	49	67	0	Clear	100
6	85	60	72	.35	Cloudy	47
7	86	62	74	0	Clear	100
8	89	59	74	0	Clear	100
9	94	67	80	.02	Cloudy	69
10	80	58	69	0	Clear	81
11	86	56	71	0	Partly cloudy	83
12	83	58	70	.13	Cloudy	41
13	81	53	67	0	Clear	96
14	84	54	69	0	Partly cloudy	99
15	90	61	76	0	Partly cloudy	79
16	88	61	74	.02	Cloudy	43
17	76	53	64	0	Partly cloudy	75
18	78	48	63	0	Clear	99
19	81	42	62	0	Clear	100
20	83	56	70	T	Partly cloudy	73
21	87	62	74	0	Partly cloudy	56
22	81	64	72	T	Partly cloudy	39
23	87	63	75	.01	Partly cloudy	59
24	90	63	76	.01	Partly cloudy	56
25	84	59	72	0	Clear	93
26	87	53	70	.68	Clear	92
27	84	60	72	.26	Partly cloudy	99
28	83	55	69	0	Clear	100
29	86	60	73	.05	Partly cloudy	92
30	78	54	66	0	Clear	96
31	78	48	63	0	Clear	99
Mean	84.6	57.4	71.0	Total. 1.53		

Atmospheric Pressure. (Reduced to sea level; inches and hundredths.)—Mean, 29.92; highest, 30.28; date, 19; lowest, 29.69; date, 24.

Temperature.—Highest, 97; date, 1; lowest, 42; date, 19; greatest daily range, 39; date, 19; least daily range, 17; date, 22.

Precipitation.—Total this month, 1.53; snowfall, 0; greatest precipitation in 24 hours, .94; date, 26 and 27; snow on the ground at end of month, 0.

Wind.—Prevailing direction, southwest; total movement, 3710 miles; average hourly velocity, 5.0; maximum velocity (for five minutes), 25 miles per hour, from south, on 9.

Weather.—Number of days, clear, 14; partly cloudy, 13; cloudy, 4; on which .01 inch, or more, of precipitation occurred, 9.

Miscellaneous Phenomena (dates of).—Auroras, ; halos: solar, 0; lunar, 0; hail, 0; sleet, 0; fog, 0; thunderstorms, 6, 9, 15, 16, 22, 24, 6,2 27, 29; *frost: light, 19; heavy, 0; killing, 0.

Note.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing."

DEWEY A. SEELEY,
Local forecaster, Weather Bureau.

Meteorological observations for the month of August, 1910, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percent of sunshine.
1	78	55	66	.04	Cloudy	0
2	83	60	72	0	Partly cloudy	66
3	84	64	74	.19	Cloudy	57
4	76	48	62	0	Clear	76
5	75	46	60	0	Clear	100
6	80	49	64	0	Clear	99
7	74	55	64	0	Cloudy	15
8	84	54	69	T	Clear	86
9	79	61	70	.03	Cloudy	32
10	81	58	70	T	Clear	97
11	80	50	65	0	Clear	98
12	85	52	68	0	Clear	100
13	87	55	71	0	Partly cloudy	72
14	90	59	74	0	Partly cloudy	68
15	89	62	76	T	Partly cloudy	64
16	85	65	75	T	Cloudy	58
17	90	64	77	.30	Partly cloudy	62
18	73	52	62	T	Cloudy	37
19	77	49	63	0	Clear	97
20	78	55	66	0	Partly cloudy	86
21	87	60	74	.01	Partly cloudy	93
22	84	66	75	0	Cloudy	55
23	75	62	68	.45	Cloudy	10
24	86	69	78	0	Cloudy	21
25	77	52	64	.63	Cloudy	0
26	70	44	57	0	Clear	96
27	74	44	59	0	Clear	88
28	78	51	64	0	Clear	78
29	76	56	66	0	Cloudy	61
30	85	60	72	.09	Partly cloudy	71
31	74	58	66	.02	Cloudy	42
Mean	80.5	56.0	68.2	Total. 1.76		

Atmospheric Pressure.—(Reduced to sea level; inches and hundredths.)—Mean, 30.01; highest, 30.26; date, 19; lowest, 29.72; date, 3.

Temperature.—Highest, 90; date, 17; lowest, 44; date, 26; greatest daily range, 33; date, 12; least daily range, 13; date, 23.

Precipitation.—Total this month, 1.76; snowfall, none; greatest precipitation in 24 hours, .63; date, 25; snow on the ground at end of month, none.

Wind.—Prevailing direction, south; total movement, 3675 miles; average hourly velocity, 4.9; maximum velocity (for five minutes), 20 miles per hour, from northwest, on 25.

Weather.—Number of days, clear, 11; partly cloudy, 8; cloudy, 12; on which .01 inch, or more, of precipitation occurred, 9.

Miscellaneous Phenomena (dates of).—Auroras, 0; halos: solar, 0; lunar, 0; hail, 0; sleet, 0; fog, 17; thunderstorms, 1, 3, 9, 10, 15, 17, 21, 23, 25; *frost: light, 0; heavy, 0; killing, 0.

Note.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing."

DEWEY A. SEELEY,
Local forecaster, Weather Bureau.

Meteorological observations for the month of September, 1910, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percent of sunshine.
1	68	51	60	0	Cloudy	45
2	77	42	60	0	Clear	86
3	79	58	68	.01	Cloudy	33
4	67	57	62	.32	Cloudy	0
5	79	64	72	.35	Cloudy	5
6	78	55	66	0	Partly cloudy	70
7	81	52	66	0	Clear	95
8	80	58	69	0	Cloudy	32
9	64	44	54	0	Clear	100
10	68	38	53	0	Clear	100
11	76	41	58	0	Clear	100
12	74	53	64	.02	Cloudy	8
13	66	45	56	0	Partly cloudy	78
14	71	41	56	0	Clear	97
15	75	41	58	0	Clear	100
16	76	43	60	0	Clear	100
17	76	47	62	.36	Partly cloudy	62
18	71	52	62	0	Cloudy	26
19	68	51	60	0	Cloudy	15
20	71	50	60	0	Partly cloudy	52
21	74	46	60	0	Clear	90
22	70	37	54	0	Clear	100
23	62	53	58	1.07	Cloudy	0
24	71	55	63	.30	Cloudy	9
25	60	54	57	.01	Cloudy	0
26	65	52	58	.10	Cloudy	35
27	64	52	58	.20	Cloudy	14
28	68	45	56	0	Clear	95
29	70	42	56	0	Clear	100
30	75	49	62	0	Clear	88
Mean	71.5	48.9	60.2	Total. 2.74		

Atmospheric Pressure.—(Reduced to sea level; inches and hundredths.)—Mean, 30.09; highest, 30.41; date, 14; lowest, 29.78; date, 3.

Temperature.—Highest, 81,; date 7; lowest, 37; date, 22; greatest daily range, 35; date, 2; least daily range, 6; date, 25.

Precipitation.—Total this month, 2.74; snowfall, 0; greatest precipitation in 24 hours, 1.31; date, 23 and 24; snow on the ground at end of month, 0.

Wind.—Prevailing direction, south; total movement, 3456 miles; average hourly velocity, 4.8; maximum velocity (for five minutes), 18 miles per hour, from southwest, on 6.

Weather.—Number of days, clear, 13; partly cloudy, 4; cloudy, 13; on which .01 inch, or more, of precipitation occurred, 10.

Miscellaneous Phenomena (dates of.)—Auroras, 0; halos: solar, 26.30; lunar, 0; hail, 0; sleet, 0; fog, 19 and 20; thunder-storms, 4, 5, 7, 8, 17; *frost: light, 0; heavy, 0; killing, 0.

Note.—"T" indicates trace of precipitation.

*Frosts are not recorded after the occurrence of "killing."

DEWEY A. SEELEY,
Local forecaster, Weather Bureau.

Meteorological observations for the month of October, 1910, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percent of sunshine.
1	69	44	56	0	Clear	99
2	64	36	50	0	Clear	90
3	82	52	67	.22	Partly cloudy	54
4	67	63	65	.82	Cloudy	0
5	74	55	64	.06	Cloudy	24
6	55	35	45	.35	Cloudy	6
7	61	31	46	0	Clear	100
8	65	34	50	0	Clear	92
9	54	37	46	0	Partly cloudy	32
10	64	33	48	0	Clear	100
11	72	44	58	0	Clear	100
12	55	37	46	0	Partly cloudy	58
13	66	36	51	0	Clear	98
14	77	48	62	0	Clear	91
15	70	48	59	0	Clear	64
16	74	52	63	0	Clear	74
17	79	50	64	0	Clear	99
18	82	52	67	0	Clear	100
19	81	57	69	0	Clear	100
20	60	46	53	0	Cloudy	0
21	58	45	52	.56	Cloudy	0
22	51	41	46	.03	Cloudy	23
23	56	33	44	0	Clear	87
24	62	41	52	0	Cloudy	19
25	57	38	48	0	Partly cloudy	50
26	49	36	42	.11	Cloudy	5
27	49	32	40	.12	Cloudy	29
28	40	28	34	0	Cloudy	18
29	40	23	32	0	Partly cloudy	60
30	50	30	40	0	Clear	77
31	64	32	48	0	Clear	98
Mean	62.8	40.9	51.8	Total. 2.27		

ATMOSPHERIC PRESSURE.—(Reduced to sea level; inches and hundredths.)—Mean, 30.02; highest, 30.43; date, 7; lowest, 29.51; date, 26.

TEMPERATURE.—Highest, 82; date, 18; lowest, 23; date, 29; greatest daily range, 32; date, 31; least daily range, 4; date, 4.

PRECIPITATION.—Total this month, 2.27; snowfall, 0.0; greatest precipitation in 24 hours, .93; date, 3 and 4; snow on the ground at end of month, 0.

WIND.—Prevailing direction, southwest; total movement, 4401 miles; average hourly velocity, 5.9; maximum velocity (for five minutes), 24 miles per hour, from southwest, on 3.

WEATHER.—Number of days, clear, 16; partly cloudy, 5; cloudy, 10; on which .01 inch, or more, of precipitation occurred, 8.

MISCELLANEOUS PHENOMENA (dates of).—Auroras, 0; halos: solar, 24, 30; lunar, 13, 15; hail, 0; sleet, 0; fog, 0; thunderstorms, 3, 5; *frost: light, 2; heavy, ——; killing, 7.

*Frosts are not recorded after the occurrence of "killing."

DEWEY A. SEELEY,
Local forecaster, Weather Bureau.

Meteorological observations for the month of November, 1910, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percent of sunshine.
1	56	36	46	.14	Cloudy	12
2	43	32	38	.01	Cloudy	50
3	42	26	34	0	Cloudy	10
4	44	22	33	0	Clear	95
5	37	29	33	.03	Cloudy	0
6	35	27	31	0	Cloudy	2
7	37	26	32	0	Cloudy	22
8	44	27	36	0	Clear	80
9	63	36	50	.01	Partly cloudy	45
10	48	30	39	.07	Cloudy	0
11	36	26	31	.01	Cloudy	14
12	40	30	35	0	Cloudy	6
13	41	32	36	0	Cloudy	3
14	33	29	31	.08	Cloudy	0
15	36	31	34	0	Cloudy	0
16	34	30	32	0	Cloudy	0
17	30	28	29	0	Cloudy	0
18	30	28	29	.01	Cloudy	0
19	39	23	31	0	Partly cloudy	73
20	42	21	32	0	Partly cloudy	82
21	38	26	32	.05	Cloudy	0
22	40	26	33	0	Cloudy	25
23	43	33	38	.16	Cloudy	0
24	39	29	34	.16	Cloudy	0
25	44	30	37	0	Partly cloudy	32
26	38	28	33	0	Partly cloudy	74
27	35	30	32	.12	Cloudy	0
28	34	31	32	.31	Cloudy	0
29	32	25	28	.02	Cloudy	0
30	31	25	28	.19	Cloudy	0
Mean	39.5	28.4	34.0	Total. 1.37		

Atmospheric Pressure.—(Reduced to sea level; inches and hundredths.)—Mean, 29.94; highest, 30.31; date, 4; lowest, 29.61; date, 7.

Temperature.—Highest, 63; date, 9; lowest, 21; date, 20; greatest daily range, 27; date, 9; least daily range, 2; date, 1.

Precipitation.—Total this month, 1.37; snowfall, 5.9; greatest precipitation in 24 hours, .43, date, 27 and 28; snow on the ground at end of month, 3.0.

Wind.—Prevailing direction, northwest; total movement, 5664 miles; average hourly velocity, 7.9; maximum velocity (for five minutes), 24 miles per hour, from northwest, on 10.

Weather.—Number of days, clear, 2; partly cloudy, 5; cloudy, 23; on which .01 inch, or more, of precipitation occurred, 15.

Miscellaneous Phenomena (dates of).—Auroras, 0; halos: solar, 8, 20; lunar, 8; hail, 0; sleet, 0; fog, 0; thunderstorms, 0.

DEWEY A. SEELEY,
Local forecaster, Weather Bureau.

Meteorological observations for the month of December, 1910, at Agricultural College, East Lansing, Michigan.

Date.	Temperature. (Degrees Fahrenheit.) Maximum.	Minimum.	Mean.	Precipitation. (In inches and hundredths.)	Character of day.	Percent of sunshine.
1	30	23	26	0	Cloudy	0
2	28	22	25	0	Cloudy	0
3	27	19	23	.04	Cloudy	0
4	31	13	22	0	Partly cloudy	42
5	25	17	21	0	Cloudy	14
6	25	16	20	0	Cloudy	0
7	25	16	20	.10	Cloudy	0
8	21	12	16	.01	Cloudy	0
9	23	-2	10	0	Partly cloudy	99
10	22	8	15	.17	Cloudy	0
11	28	18	23	.06	Cloudy	0
12	30	16	23	0	Cloudy	9
13	28	18	23	0	Partly cloudy	38
14	37	22	30	0	Clear	91
15	34	4	19	0	Partly cloudy	64
16	22	-2	10	0	Cloudy	63
17	33	14	24	0	Clear	96
18	37	23	30	.07	Cloudy	17
19	30	15	22	.05	Cloudy	0
20	19	7	13	.02	Cloudy	13
21	25	9	17	0	Partly cloudy	70
22	33	11	22	.04	Cloudy	7
23	34	25	30	.05	Cloudy	4
24	25	12	18	.01	Cloudy	0
25	22	7	14	.15	Partly cloudy	27
26	31	19	25	0	Cloudy	0
27	38	19	28	0	Clear	96
28	35	29	32	.36	Cloudy	0
29	34	25	30	.15	Cloudy	0
30	25	5	15	0	Clear	73
31	34	8	21	0	Partly cloudy	50
Mean	28.7	14.5	21.6	Total. 1.28		

Atmospheric Pressure.—(Reduced to sea level; inches and hundredths.)—Mean, 30.08; highest, 30.69; date, 13; lowest, 29.49; date, 19.

Temperature.—Highest, 38; date, 27; lowest, -2; date, 16; greatest daily range, 30; date, 15; least daily range, 6; date, 2.

Precipitation.—Total this month, 1.28; snowfall, 19.8; greatest precipitation in 24 hours .36; date, 28; snow on the ground at end of month, 9.0.

Wind.—Prevailing direction, southwest; total movement, 5252 miles; average hourly velocity, 7.1; maximum velocity (for five minutes), 24 miles per hour, from northwest, on 15.

Weather.—Number of days, clear, 4; partly cloudy, 7; cloudy, 20; on which .01 inch, or more, of precipitation occurred, 14.

Miscellaneous Phenomena (dates of).—Auroras, 0; halos: solar, 9, 13, 17, 27, 31; lunar, 13, 14; hail, 0; sleet, 0; fog, 4; thunderstorms, 0.

DEWEY A. SEELEY,
Local forecaster, Weather Bureau.

REPORT OF THE MICHIGAN WEATHER SERVICE.

FOR THE FISCAL YEAR ENDING JUNE 30, 1911.

The operation of the Weather Service has been confined to the general lines of endeavor that have prevailed for some years past and of these, the collection, compilation and filing of detailed records from voluntary observers is the principal one.

The service was inaugurated to cooperate with the United States Weather Bureau and secure in detail a thorough knowledge of Michigan climatic conditions and it is very admirably accomplishing this result. There are ten regular Weather Bureau Stations in the state. All but two of them, Grand Rapids and Lansing, are lake shore observatories. There were at the close of the fiscal year, one hundred and thirteen cooperative, or voluntary observation stations from which reports were received monthly. All of these stations keep a record daily of the highest and lowest temperature, amount of precipitation, if any, general or prevailing direction of the wind and general character of the day as regards cloudiness. The observers also note the actual depth of the snow on the ground from day to day, if there is any, and under miscellaneous phenomena, keep a record of the occurrence of frost and other irregular meteorological data. The voluntary observers as a general rule, have been and are now doing splendid work and their reports are very reliable, regular and prompt.

The value of the observations, which are taken entirely by public spirited or interested citizens without any pay whatever, is of untold importance to the state at large. The records find a wider and more extensive use from year to year and are a very important factor in developing the agriculture of the state.

As agriculture has developed, the influence of climate in all its phases has become a recognized factor. The records of the Michigan Weather Service supply detailed and valuable information on this subject for nearly every general locality and for every section of the state. For instance, we have just been able to draw graphic charts showing the average occurrence of the last killing frost in spring and the first killing frost in autumn; the time between these dates shows the average length of the crop growing season. Additional charts have also been published showing the occurrence of the last known killing frost in spring and the earliest known killing frost in autumn. Reference to these charts develops the fact that all of the Lower Peninsula of Michigan has a much longer crop growing season than other states in the same latitude.

Besides their use for scientific purposes, the records are entering into many other fields of development of the state's resources. In locating water plants a long record of rainfall in connection with the stream flow, is of insistent and decided value. The records are constantly being used in a large variety of law cases to settle disputed points regarding weather conditions, and they furnish valuable information to the medical fraternity and the civic engineer.

In the distribution of the daily weather forecasts, the service has received great aid from all of the telephone companies in the state. The rural telephone is reaching out rapidly to the farming districts and any rural subscriber, as well as the city man, can now get the weather forecasts at 11 a. m., or after, by simply calling up his "central" and asking for it. This service is promoted by the telephone companies practically without cost to the state or government, because the telephone companies find it makes their phones more desirable and in that way increases their business. I have inaugurated and have had in operation in Michigan for some years, a very complete system of telephone distribution, particular attention being given to reaching rural subscribers. The value of the forecast in case of frost, a cold wave or of rain during the growing and harvesting seasons is very great and as the farmer is becoming acquainted with the Weather Bureau, he is learning to appreciate this service more and more.

The publishing of the monthly reports has been taken over by the United States Weather Bureau, but their dissemination continues as before; any citizen of Michigan who desires them and can show any reason for their use, can secure these reports by asking for them.

Besides the monthly reports, there has been issued a Special Climatology of Michigan, which is published in three parts, one for the Upper Peninsula, one for the western half of the Lower Peninsula and one for the eastern half.

These climatologies discuss the general climate of the state and give in detail, for a long period of years, monthly and yearly temperature averages and precipitation amounts. Last frosts in spring and first in autumn for a number of places are also displayed by tables. Besides meteorological data, a special reference is made to the topography and river systems of the state.

C. F. SCHNEIDER,
Section Director.

Dated at Grand Rapids, Mich., June 30, 1911.

REPORT OF SUPERINTENDENT OF FARMERS' INSTITUTES.

President J. L. Snyder:

Sir:—As never before, the farmers of Michigan seem to be alive to the benefits that may be secured from Farmers' Institutes. From the fact that there had been no increase in the amount appropriated for Farmer's Institutes, it was evident from the very opening of the year that it would not be possible to hold more institutes than in the previous year and, as it had been necessary for several seasons to restrict the number of meetings, it was not deemed necessary nor advisable to urge upon the local officers the holding of more institutes than in 1909-10. Notwithstanding this, a considerable number of the counties asked for an increase in their allotment and many more meetings could have been held had the funds permitted.

There has been no change in the method of looking after the local ar-

rangements, this being in the hands of the county institute societies. The work of arranging the institutes falls largely upon the county secretaries but, in many of the counties, this work has been shared by the president and in nearly every case where one-day institutes have been held, the township vice-presidents have acted efficiently as local managers.

In addition to the holding of a two-day institute in each county there was a very noticeable increase in the number of counties desiring one-day institutes which made it necessary to lessen the number that could be allowed to the other counties. While in a few cases only one or two one-day institutes are desired, in a great majority of the counties, nothing less than five or six will answer and several of them called for twelve to fifteen.

In order to do the work required of the secretary of the county institute society and especially if a half-dozen or more one-day institutes are held, the expenditure of a considerable amount of time is necessary. While it has not been difficult in most counties to find some one who will take the work for one or perhaps two years, few persons feel that they can give the time required for a longer period. This has necessitated frequent changes and as the new officers are not familiar with their duties it has resulted in placing upon this office a large amount of extra work. Even when the secretary of a county institute society is fully informed regarding his duties and entirely efficient, it has occasionally happened that some of the local managers who have been relied upon to look after the work of advertising and arranging for the meetings have failed to do so and the success of the institutes has been greatly reduced. I am glad to say, however, that in most cases not only have the secretaries been very efficient and conscientious in performing the duties of their position but the local managers also have done excellent work.

INSTITUTE LECTURERS.

During the year several additions have been made to the corps of institute lecturers and without exception they have shown marked ability and have met with unusual success. The duties of institute lecturers are by no means as easy as they are generally supposed to be. Aside from the physical discomforts to which they are exposed from traveling in all kinds of weather often taking long drives in the early morning or late at night and sleeping in a cold room after spending hours in a hot and poorly ventilated hall, the lecturer must be prepared to give two or three talks each day that will instruct and interest a somewhat critical audience. He is criticised if he is not prepared to give definite answers to all of the questions which may be put to him however remote they may be from the topics which have been assigned him upon the program and those upon which he has arranged to speak. On the other hand he is blamed if he gives the experience of others when he has not himself had practical experience along some of the lines under discussion.

In the selection of speakers to handle topics along practical farming lines an endeavor has been made to select men who have themselves made a success in farming and who are able to present their views in

a clear and interesting manner. As nearly all of the common operations of the farm are based upon natural laws, the better understanding a lecturer has of these laws and their relation to the handling of the soil and the growth of animals and plants, the more valuable, everything else being equal, will he be as an institute lecturer.

ONE-DAY INSTITUTES.

During the year now closing there have been held in Michigan 368 one-day institutes at which 84,924 persons have been present as determined by actual count at each of the sessions. The usual plan of furnishing one speaker upon farming topics has been followed and the local managers have been urged to secure as local speakers for the forenoon and afternoon sessions two farmers who will outline the methods they have used in growing some of the crops or handling some of the classes of animals in which the farmers of the section are particularly interested. It has not been found advisable to have more than two subjects on the program for the forenoon and three for the afternoon sessions. As a third speaker for the afternoon some lady upon topics relating to the home or such other matters as might be of general interest has often been selected.

In quite a number of the counties arrangements have been made with the county commissioner of schools to furnish a speaker upon some educational topic who would appear in the afternoon and again for the evening program. This plan has very generally given satisfaction but in a few cases where local speakers were not upon the program or where they failed to appear it was felt that too little time was given to topics relating to farm work. The importance of having local speakers upon the program should not be overlooked. It should not be difficult in any farming community to find one or two farmers who have been particularly successful in some line of agriculture or who have had experience which will be of value to their brother farmers. It will not be necessary and in most cases is not desirable to have them prepare a "paper" but if they will merely state the methods they have used and the results they have obtained the matter can then be thrown open for discussion and much valuable information which will be of general interest will be brought out.

The value of the Grange and Farmers' Clubs and similar organizations has many times been shown at the one-day institutes. Not only have they been helpful by supplying halls in which the meetings can be held but an attendance is generally assured when an institute is located in a section where such organizations exist. It is also an easy matter to secure speakers to fill out the program and there is generally no difficulty about securing a lively discussion.

COUNTY INSTITUTES.

Nearly all of the counties have availed themselves of the privilege of having a two-day county institute and in fact several counties instead of having four to six one-day institutes have expressed a choice for the holding of two or three two-day institutes. While this has seemed to answer very well in quite a number of places in a great majority of

the counties it is undoubtedly better to held to the plan of having only one of the institutes last more than one day and that the county institute. This plan makes it possible to bring an institute within easy reach of nearly all the farmers in a county. As now conducted the cost of the county institutes is much greater than that of the one-day meetings. Not only do they last twice as long but instead of one speaker whose entertainment and transportation about the county is looked after by the local management, three and sometimes four speakers are furnished and their traveling expenses and hotel bills are paid from the State institute funds.

With very few exceptions separate sections have been held for the women in connection with the county institutes and in most instances where it has been put to a vote a request has been made for the holding of women's sections during the coming year. The criticism that the women are interested in all of the topics upon the program for the general session and that the men are equally interested in the topics discussed at the women's session is sometimes heard but it is seldom possible to find time for all of the topics upon the programs of the general sessions and however much the women may be interested in the general session or the men in the topics on the program for the women's section in most cases they will be most benefited by following the program as planned, especially as each can learn from the other what has been said. From the very beginning of the women's sections it has always been reported that the women have entered more freely into the discussion of topics relating to the home in the women's section than when upon the program for the general session. In many places it is difficult to find a hall sufficiently large to hold all who wish to attend the farmers' institute but by meeting in two sections the trouble is solved. For these, and other reasons the holding of women's sections in connection with the county institutes is strongly advised.

In making out the programs for the county institutes there is always opportunity for using one or two local speakers. The opportunity should not be neglected as it will often strengthen the program and at the same time prove perhaps even more helpful to the speakers themselves.

Through the kindness of Prof. W. J. Spillman, we were favored by the presence of Prof. C. B. Smith, of the Bureau of Farm Management, U. S. Dept. of Agriculture, at a number of the county institutes in northeastern Michigan. Many complimentary reports upon his work have been received as has also been the case with Prof. W. J. McDowell of the same Bureau, who was with the institute train for twelve days.

Prof. Smith formerly lived in Montmorency county and is now the owner of a farm near Atlanta. This with his work for the Department of Agriculture, which in part consists in studying the problems of the pine plains, made him a valuable man for the work and it certainly was highly appreciated by this office as well as by the farmers who met him.

For most of the county institutes it has been the custom to send two lecturers upon farming topics and one lady speaker and during the last year a speaker furnished by the courtesy of Hon. Townsend A. Ely, State Highway Commissioner, has also been present at most of the meetings. Frank F. Rogers, Deputy State Highway Commissioner,

who has received most of the assignments was everywhere listened to with the best of attention and his addresses made at the farmers' institutes will undoubtedly have much weight in the campaign for better roads.

The cause of education has also been upon the program for most of the county institutes and quite a number of the county commissioners and members of the faculties of the normal schools have taken part.

From the fact that speakers at the one-day institutes usually make the tour of a county and because they are not able to leave their classes for any length of time, very few of the faculty of the Michigan Agricultural College and of the Experiment Station staff have attended the one-day institutes but a considerable number have been upon the programs for the county institutes.

ROUND-UP INSTITUTE.

Owing to the action taken two years ago by the Board of Agriculture which voted to hold the Round-up Institute each year at the Agricultural College a change was made from the former plan of meeting there upon alternate years only and a program was arranged for the holding of the Round-up Institute at the Agricultural College on February 28, March 1, 2 and 3.

The live stock pavilion was used for the general session and several of the adjacent rooms were given up to exhibits. The general plan of the program was the same as used last year, particular attention being given to topics relating to the soil and to the production of farm crops. This course was adopted from the fact that live stock topics had received attention at meetings held under auspices at about the same time. The meeting of the State Dairymen's Association occurred on the week previous while "Farmers' Weeks" at which special attention was given to poultry and dairying were held at the college respectively just before and after the Round-up Institute. The State Live Stock Breeders also had their annual meeting at the college in January.

The program called for a continuation of the plan adopted last year and Professor J. A. Jeffery, Professor F. S. Kedzie and Professor V. M. Shoesmith took up the topics in the series assigned to them and each gave four lectures, using about thirty minutes after which an equal period was allowed for questions and discussion. The idea seemed to meet with general approval. The program for three afternoon and three evening sessions was of a more general nature. Among the topics receiving particular attention being: Fruit Growing; Corn Culture; Alfalfa Growing; Dairying and Stock Feeding. At the evening sessions House Heating; Gravel Roads; Play Grounds; Boys and Girls; Farmers' Institute lecturers and the work of the Agricultural College were among the subjects discussed.

Aside from the institute lecturers and members of the college faculty who took part in the program, were Willis O. Wing, Mechanicsburg, Ohio; Professor G. C. Humphrey, University of Wisconsin; Professor Wm. A. McKeever, Kansas Agricultural College; Professor John Hamilton, Farmers' Institute Specialist, U. S. Department of Agriculture; Professor S. T. Maynard, Northboro, Mass., and John I. Gibson, Man-

ager of the West Michigan Development Bureau. The addresses so far as the manuscripts have been furnished, will be printed in the report.

A Women's Congress was held on Thursday and Friday afternoons and among the speakers were Mrs. H. H. Fulcher, St. Louis and Miss Ida L. Chittenden, Lansing.

EXHIBITS.

More than usual attention was paid to the securing and installation of exhibits. The large show room used by the farm mechanics department was secured for an exhibit of spraying machinery. The Association of Manufacturers of Spraying Machinery and Supplies aided materially in obtaining and advertising this exhibit. It was participated in by all of the leading manufacturers of power spraying machinery located in Michigan as well as several from other states; and, as many of them exhibited two or three power outfits, the showing was not only very large but quite complete and instructive. Among those participating were: The Air Cooled Engine Company, Lansing; Brown-Bair Motor Company, Grand Ledge; Champion Mfg. Company, Pontiac; Beck Motor Company, Lansing; M. D. Buskirk, Paw Paw; Fairbanks, Morse & Co., Chicago; Goulds' Force Pump Co., Seneca Falls, N. Y.; Hardie Mfg. Co., Hudson, Mich.; E. C. Brown & Co., Rochester, N. Y.; Hildreth Mfg. Co., Lansing; International Harvester Co., Chicago; New-Way Motor Co., Lansing.

In the way of spraying supplies the only exhibitors were, Dow Chemical Co., Midland, and the Devoe & Raynolds Co., Chicago. E. M. Hunt, Lansing, had a very complete exhibit of bee-keepers' supplies.

One of the most interesting exhibits was made by the West Michigan Development Bureau. This included some fifty boxes of apples grown in Michigan in 1910. They not only showed what can be done in Michigan in the way of apple growing when orchards are given proper attention as in size and color they were fully equal to the product of any other part of the country and far surpassed most other apples in flavor and aroma but they demonstrated the superior keeping qualities of Michigan apples as this same fruit had been shown in a hot room for two weeks at the Chicago Land Show and for shorter periods at one or two other meetings and were still firm and with little change in color. Exhibits of fruits preserved in liquids were also made showing the adaptation of northwestern Michigan to the growing of peaches, plums, cherries and other summer fruits.

The Horticultural Department of the Experiment Station had a very interesting exhibit of apples showing the comparative results obtained from spraying with Bordeaux mixture and lime sulphur solution. Not only were the fruits sprayed with lime and sulphur much freer from scab but they seemed to be larger, better colored and entirely free from any injury due to the spraying material. While some of the specimens upon which Bordeaux mixture had been used were quite free from injury, many of the varieties were badly russetted.

The Farm Crops Department had an exhibit of grains which attracted considerable attention. It contained a large number of varieties of wheat, both straw and grain being shown and specimens illustrating the effect of selection with timothy and alfalfa.

The Bacteriological Department showed cultures of various kinds and specimens of animal tissue diseased with hog-cholera, tuberculosis and other bacterial troubles.

During the Institute visitors found time to examine the equipment of the other departments and found much of interest in all of them. The college barns, greenhouses, laboratories and museum seemed to attract the most attention.

MUSIC.

The afternoon and evening sessions of the Institute were enlivened by a number of musical selections. For Wednesday afternoon the music was furnished by the orchestra of the State Industrial School for boys; and on Friday afternoon the Industrial School choir was present and rendered several selections. On Thursday afternoon the orchestra and choir of the State School for the Blind furnished the music. For the other sessions the music was supplied by college talent, —the College Band, College Orchestra, College Choir and several soloists being on the program for the different sessions. The arrangement of the music was in the hands of Miss Louise Freyhofer, instructor in music at the college, and acknowledgment for the services of the different organizations is hereby made to Supt. E. M. Lawson, of the Industrial School, Supt. C. E. Holmes, of the School for the Blind, Prof. A. J. Clark, Director of the College Band, and the leaders and members of the other musical organizations.

WOMEN'S CONGRESS.

Upon Thursday and Friday afternoons special sessions for the women were held and the attendance and interest compared well with other years. The topics discussed with the papers and discussion are given in the report. The subjects related largely to the training and care of children.

In order to interest the ladies while topics relating to the soil and farm crops were being presented in the general session arrangements were made for special demonstrations on Wednesday, Thursday and Friday forenoons. These were held in the Women's Building, college greenhouses, Engineering Building, Bacteriological Laboratory and poultry houses.

INSTITUTE TRAINS.

During the latter part of March and the first week in April a "Better Farming" institute train was run over three of the railroads,—the Grand Trunk, the Pere Marquette and the Grand Rapids and Indiana. The main line of the Grand Trunk from Vicksburg to Port Huron was traversed, also the Grand Haven division between Durand and Coopersville. Upon the Pere Marquette a run was made from Grand Rapids to Petoskey, including a side trip from White Cloud to Hart. The Grand Rapids and Indiana furnished a train from Petoskey in the extreme northern part of the state to Sturgis which is very near the Indiana line. Five days were spent upon each of the above roads and the train made six stops each day.

In its equipment the "Better Farming" train of 1911 did not differ

materially from that of 1910. There were three passenger coaches in which five or six talks of five minutes each were given after which the visitors were taken through the exhibit cars. One of these contained a complete outfit of dairy machinery, including milk testers, separators, churns and butter workers; another contained a dozen or more breeds of poultry, models of poultry houses, samples of poultry feed, etc. A third car was occupied by the bacteriological exhibit which did not differ materially from that shown at the Round-up Institute. The fourth car was utilized for an exhibit of grain and forage crops and for an exhibit by the horticultural department illustrating pruning, grafting, spraying and the use of cover crops. Samples of some of the more dangerous insects and diseases and remedies for them were also displayed.

The attendance throughout the entire trip exceeded that in any previous year except upon one or two days when the weather was quite stormy. At a very large proportion of the places where stops were made the number reached 300 to 350 persons which was about as many as could be readily accommodated upon the train. The attendance at Coopersville, Fremont, Shelby, Bellaire and Reed City ranged from 500 to 550 and for the twelve days with 61 stops there was an attendance of 18,800.

Among those who were with the train as lecturers or demonstrators were Prof. J. C. McDowell, of the Farm Management Bureau, U. S. Department of Agriculture; W. F. Raven and A. R. Potts, Field Agents; Prof. C. P. Halligan and Instructor O. I. Gregg, of the Horticultural Department; W. B. Liverance of the Dairy Department; Dr. Ward Giltner of the Bacteriological Department and H. L. Kempster and J. O. Linton of the Poultry Department. L. W. Hopkins and C. H. Knopf acted as demonstrators.

Especial interest was shown in the lectures and exhibits relating to alfalfa and spraying although all of the lines illustrated received careful attention.

EXHIBITS AT THE INSTITUTES.

One of the features which has been quite generally introduced at the county institutes and which has received some attention at the one-day institutes has been the exhibits of farm crops and work of the public schools. In some counties considerable prizes have been offered for the best exhibits of corn, grains, potatoes and other farm crops grown by farmers while in others a part or all of the prizes have been limited to crops grown by boys or girls under eighteen years of age. In several counties boys' corn clubs have organized under the auspices of the county institute societies and especially where they have had the cooperation of the county commissioner of schools they have resulted in bringing out a large number of exhibits many of which compare very favorably with those shown in the classes for adults. In a few counties the prizes have also been offered for the best loaves of bread, samples of plain sewing, etc. exhibited by girls.

Wherever this work has been taken up it has not only added to the attendance and interest at the institutes but it will also undoubtedly have a beneficial effect upon rural life in Michigan for years to come.

If funds were provided for the purpose the work could be so directed and systematized as to extend the work over the state and bring it to the attention of the boys and girls of every township.

INSTITUTE SCHOOLS.

For several years the plan of holding institute schools in different parts of the state has been advocated and the time now seems ripe for doing so. At the regular institutes the discussion has related largely to the methods of growing farm crops and the care of domestic animals but, while there is still a broad field for further work along this line, there are many thousands of farmers in Michigan who are thirsting for a knowledge of the natural sciences which underlie all of the operations of the farm. They are not able to leave home to attend the Agricultural College even for the short courses and yet would gladly attend an institute school lasting four or five days if one could be held within a short distance of their homes. To take up this work would either require an increase of the present force of instructors at the college which would make it possible for three or four men from as many departments to leave their work at the college for two or three months during the winter, or the organization of a corps of lectures for conducting institute schools.

In a number of the states from $15,000 to $25,000 annually are spent for this class of extension work in addition to an equal amount used for farmers' institutes. For a number of years the amount that has been available for the holding of the regular farmers' institutes, aside from the amount used for the Round-up Institute, institute trains, printing and mailing the annual institute report, and for administration and office expenses, has been little if any more than $5,000. In very few of the neighboring states is the appropriation for institutes less than $20,000 and in several of them it is more than $30,000 per year.

The cost of holding a one-day institute varies from $2.00 to $2.50 per session where three sessions are held while for the county institutes with three or four speakers it is not far from $10.00 per session. The average cost of the regular institutes is less than $5.00 a session, or a little more than three cents for each person in attendance. The reports received from the officers of county institute societies indicate that there is a demand for a considerable increase in the number of meetings and as this will call for but a slight additional expense, the holding of more meetings in places where there is sufficient interest to warrant it is heartily recommended.

Respectfully submitted,

L. R. TAFT,

Supt. Farmers' Institutes.

East Lansing, Mich., June 30, 1911.

REPORT OF THE STATE INSPECTOR OF NURSERIES AND ORCHARDS.

To the State Board of Agriculture:

Gentlemen: The work of nursery and orchard inspection during the past year has been mainly along three lines, viz.: First, to insure by the careful inspection of all imported stock that the seedlings and trees brought in from other countries and used by the nurserymen are free from dangerous insects and diseases; second, that the stock growing in the nurseries does not become infested before it is sent out to the fruit growers; third, by the inspection of orchards to ascertain when orchards have become infested and assist the owners to combat the difficulty.

By arrangement with the Bureau of Entomology of the United States Department of Agriculture, and the Bureau of Horticulture of the New York State Department of Agriculture, reports of the arrival of all shipments of nursery stock are received. During the year nearly 500 cases were imported into Michigan, fully three-fourths of which were consigned to parties either at Monroe or Detroit, and, except when they were of bulbs or plants not likely to be infested, the contents of the cases were carefully inspected.

In 1909 nearly every case of pear, plum and apple seedlings contained a number of the nests of the brown-tail moth, and as each nest may contain as many as 400 larvae it was not uncommon to find as many as 10,000 of these insects in a single case of seedlings.

The brown-tail moth was imported into Massachusetts, presumably upon rose bushes, some twenty years ago and it has now spread into all of the New England states. It feeds upon fruit trees and often does much harm to forest trees, especially the oaks.

There is another European insect whose importation it is of even more importance to guard against. This is the gypsy moth, an insect which may do even more harm than the brown-tail as it feeds upon a greater variety of vegetation, it being stated that the only tree, shrub or herbaceous plant upon which it is not found is tobacco.

No indication of the presence of this insect upon nursery stock has ever been found in Michigan, but it has been discovered upon European shipments in New York and Ohio.

Owing to the remonstrances that were sent to the European nurseries, upon the condition of the stock received in 1909, greater care was evidently taken to see that the stock was free from infestation, as the number in 1910 was greatly reduced and most of them were small or empty nests, and the shipments received in 1911 were practically free from them.

However, it is not deemed advisable to abandon the examination of imported stock as even though a single nest is imported it would be only a few years before it had spread all over the state and Michigan might then be in the condition of Massachusetts where over one million dollars is annually expended in controlling the brown-tail and gipsy moths.

INSPECTION OF NURSERIES.

The number of nurseries in Michigan is increasing each year, but the increase is in the number of firms engaged in growing and selling strawberry and other small fruit plants rather than in those who grow tree fruits. Not only are there some thirty parties in Michigan who grow only strawberry plants for sale, and who have taken out licenses as nurserymen, but there are twice as many more who grow plants to supply the nurseries. All of these plantations must be inspected but as a rule the time required is short.

With the spread of the San Jose scale in the state it is not strange that it has appeared upon the stock in some of the nurseries, but the care taken is such that it is not likely to be distributed upon nursery stock.

It is most often found upon stock that has been carried over for three or four years, and it has been necessary to order the complete destruction of several of such lots of trees. The nurseries have been advised to clean up all blocks of trees just as soon as possible and thus lessen the danger of their being infested.

When the San Jose scale is found in blocks of saleable trees, the infested trees are destroyed, and all others fumigated with hydrocyanic acid gas, using one ounce potassium cyanide to 100 cubic feet of space for one hour.

In case the scale is found early in the season the trees are sprayed with lime-sulphur solution at such times as will catch the larvae, and the trees are reinspected just before they are dug.

In attempting to rid a nursery of the scale in addition to destroying badly infested trees and cleaning out all trees and bushes in the vicinity which could form harboring places for them, the trees are systematically sprayed. During the dormant period one or two applications of some commercial brand of lime-sulphur solution, diluted 1 to 8, are made, and in the summer four applications with a dilution of 1 to 25, or a little stronger towards the last, are given the trees.

To have the summer sprays effectual it is important that they be given while the larvae are crawling upon the trees, or before the scale covering has turned black, as otherwise the weak solutions would not destroy them.

The exact time varies with the season, being later when the weather has been cold, but a good rule is to spray a week or ten days after the first larvae appear and again a week or two later. This applies to the first and second broods, making four sprays during the growing season.

When the applications are thoroughly made, very few trees will show the least sign of being infested. This plan should be followed in all nurseries located in sections where the San Jose scale has appeared.

Improvements in spraying machinery for use in nurseries and better knowledge of spraying methods should enable the nurseries to reduce the loss of trees to a minimum and improve the quality of the stock.

Comparatively few other dangerous insects or diseases have been found in the nurseries. Among the most troublesome has been the woolly aphis which has done considerable harm in some nurseries. The

loss can be greatly reduced if all stocks and buds are fumigated and care is taken to use new land, or rather land upon which apples have never been grown, or at least not within five or six years.

SAN JOSE SCALE IN ORCHARDS.

Many of the old and neglected orchards in the southern half of the state are showing the work of the San Jose scale, but as most of the trees are practically worthless and as, under the conditions, it will be well-nigh impossible to save them by spraying, the law has not been invoked, except in cases where they are in the vicinity of nurseries or of orchards which the owners wish to save.

Many of the trees are growing in locations where at best they cannot be made profitable, and comparatively few of the older trees are of varieties that are desirable for commercial purposes. They are so full of water sprouts and dead branches that they cannot be effectually sprayed and a great majority of the attempts would result in failure. In many cases where men have been ordered to spray their trees, the results have shown that it was done in a perfunctory manner. To ensure the proper spraying of all of the infested trees would require an army of men and then in a majority of cases it would hardly be worth the effort, as satisfactory results would not be obtained unless the trees were thoroughly pruned and the spraying kept up during the season. The average farmer does not care enough for his orchard, or have sufficient faith in the virtue of spraying to do the work properly, even though he had the time and could secure a suitable outfit.

COMMERCIAL SPRAYING.

One of the greatest helps in fighting the San Jose scale and improving the condition of Michigan orchards would be to have one or more men in each neighborhood who would purchase power spraying outfits and spray the orchards of their neighbors. Many farmers have sufficient faith in spraying to be willing to pay a fair price to get their trees sprayed, but they do not have the time and do not wish to go to the expense of purchasing an outfit, and the parties who take up the work would find it very remunerative for from three to five months in the year.

DISTRIBUTION OF THE SCALE.

While the San Jose scale is being gradually distributed in the more southern counties it does not work northward very fast. There is very little north of a line drawn from Ithaca to Ludington. In former years it was found upon single trees near Frankfort and Benzonia, and this season a number of trees in Mason and Manistee counties have been found to be infested but the fact that it is spreading northward so slowly would imply that although it may appear it is not likely to be as troublesome as in the more southern counties.

THE RESULTS ARE ENCOURAGING.

Many farmers whose orchards have been infested have found the San Jose scale to be a blessing in disguise, as they have had little difficulty

in keeping it in check and, as a result of the spraying for the scale, they have destroyed most of the other troublesome insects and have kept the dangerous diseases in check.

The marked improvement in the condition of the apple orchards in many sections of the state can be indirectly ascribed to the presence of the San Jose scale as it was found that good crops were secured where the trees were sprayed, and as a result there has been almost a revolution in the care given to the orchards, and more power orchards spraying outfits were sold in Michigan last year than in the entire period since spraying has been practiced.

PEACH YELLOWS AND LITTLE PEACH.

Both of these diseases have been more than usually troublesome during the past year. The former has become quite widespread in Oakland county and cases of the genuine "little peach" have also been found there. Both diseases are quite common in all of the southwestern counties of the state.

In most of the counties where these diseases have appeared even greater harm has been done by Little Peach than by Peach Yellows. While this may in part be attributed to the fact that its presence is more difficult to detect, as well as because comparatively few are familiar with its characteristics, it really does appear to be more virulent, and when they are both allowed to spread without restraint the orchards will be more quickly wiped out and the destruction will be more complete with Little Peach than with Peach Yellows.

On the other hand, it has been demonstrated that, if all of the infected trees in a given section are destroyed, the loss can be kept to a small per cent and by replanting where infected trees are taken out the trees will hardly be missed in the orchards. In order to have the work effectual, however, concerted action is necessary and this will in most sections require thorough and prompt action on the part of the orchard inspectors.

THE SPREAD OF THE DISEASE.

Many have claimed that the Yellows and Little Peach are spread in nursery stock, through the use either of infected pits or of buds from infected trees, but this does not seem to be based upon fact as trees have been shipped by the thousands to Benzie, Grand Traverse and other northern counties from the same nurseries as other trees which were shipped to Allegan and Kent counties, but while the latter have been attacked those shipped to the northern counties have never shown the disease. If it was in the trees there is no reason why all of them should not show it. Some may claim it was because of different climatic conditions, but thousands of cases can be found where nurseries have shipped peach trees from certain blocks to forty or more counties in Michigan, as well as to other states, and the only trees which were attacked by Yellows or Little Peach were those shipped to counties where the disease prevailed. Had the trees been infected, the appearance of the diseases would have been general, but as this was not the case the theory does not seem to hold good. It would appear then that Peach Yellows spreads chiefly in the orchards, if not entirely, and the spread seems to be mainly in the spring.

WHAT IS IT?

During the last year or two a disease has been noticed which, although it resembles Little Peach, differs from it in at least one important characteristic. While in Little Peach the fruits, which have stopped growing when of the size of a large peach pit, do not soften and ripen until after the normal time, if at all, in the cases referred to the fruit not only softens but it apparently ripens prematurely, although neither the tree nor fruit show any of the characteristics of Peach Yellows.

The fruit somewhat resembles that on trees injured by borers, but the leaves are like those on trees attacked by Little Peach, except that they seem somewhat mottled, green and yellow. The disease, whatever it may be, appears to kill the trees within three years and should be treated as a dangerous one.

COOPERATING WITH LOCAL INSPECTORS.

During the past year a large amount of time has been spent with members of local inspection boards, who have asked for assistance either because they wish information regarding their duties or because they have difficulty in having their orders carried out.

These visits have resulted both in making the local inspectors more efficient and spurring them on to do more work. It has also brought about a change in the attitude of the owners of infected orchards and a more prompt compliance with the orders of the inspectors.

UNSCRUPULOUS AGENTS.

For ten or fifteen dollars enough fruit trees can be purchased to plant an acre of orchard. If the trees for any reason prove worthless the money is wasted. This amount, while small, is more than most people care to be cheated out of, but in reality it is only a small part of what one loses when the trees set upon an acre of land, for any reason turn out a swindle. To the first cost must be added the labor of planting and of cultivating, pruning and spraying the trees, as well as the use of the land until they reach a bearing age, to say nothing of pulling out the trees when their worthlessness has been ascertained. The total may amount to five or ten times the first cost of the trees, without considering the loss of prospective profits from the orchard which should be the greatest loss of all.

For this and other reasons one cannot be too careful in purchasing trees. There is always a chance of error in the best of nurseries but too many seem to care little what they use for filling their orders.

One source of loss comes from giving orders to irresponsible dealers, or traveling agents, some of whom do not stop at any form of misrepresentation and deception, if they can secure the orders. While it may be going too far to advise against buying trees except from a nursery or agent of known standing, it will be safe not to put faith in any claims out of the ordinary.

Do not "bite" because a certain variety is claimed to be free from attack by insects or diseases, or because it is of unusual size or productiveness. Next to being led to buy new kinds because they are said

to have same wonderful characteristics, the buying of some old sort under a new name, or a name that is not recognized, is to be guarded against. Thus, one firm sells the C. de Nantes pear at a high price and people buy it as a new variety. It is really the old and common variety Clairgeau, the old name of which is Clairgeau de Nantes.

Some agents freely offer to "guarantee" their trees to do certain things, and many are caught by this, but one should not forget that he will probably never see the agent again and that at best the "guarantee" is of no value.

Many agent's contracts read, "No agent is authorized to make any change, whatever, in the terms of this contract and no changes by him will be accepted." For this reason it is not advisable to expect that any unusual promises will be carried out.

Several cases have arisen during the past year where agents who carried certificates signed by certain nurseries, stating that they were their agents, have been repudiated by the nurseries which claimed that they had only agreed to sell the trees outright to them and that the so-called agents were really doing business on their own account.

Many contracts are not properly filled out. Thus, in some cases it merely says, "100 Peach" without in any way indicating the varieties or the grade to be furnished, although the agent agreed verbally to furnish a certain variety for which the price was several times as high as for ordinary varieties. Under the contract signed by the purchaser the nursery could put in any variety he might wish to dispose of.

In view of the many fraudulent transactions by traveling tree agents, every one is advised not to enter into any agreement with an agent unless he represents some nursery of good standing, and then care should be taken that the contract specifies clearly the varieties and grades to be furnished, as well as the price to be paid for them. Before signing any contract, insist on being allowed to mail a copy to the nursery for its acceptance and be sure that the contract has been carried out before paying for the trees.

LOCAL INSPECTORS SHOULD BE APPOINTED.

With the growing interest in fruit culture in Michigan and the spread of dangerous insects and diseases, there is greater need than ever before for the appointment of local orchard inspectors in every township, village and city where such insects and diseases are known to exist.

Against the Peach Yellows and Little Peach, as well as many other diseases, united action is imperative and the same holds true to a certain extent against many of the dangerous insects. Fruit growers living where no appointments have been made should petition the township, village or city boards and insist upon the appointment of competent inspectors.

LICENSED NURSERIES AND DEALERS FOR 1910-'11.

A list of the nurseries located in Michigan and other states, as well as of the dealers licensed to sell nursery stock in Michigan, is appended:

LICENSED NURSERIES.

Allen Brothers, Paw Paw.
Ayers, C. J., Adrian.
Baldwin, O. A. D., Bridgman.
Barnes, Ben, Traverse City.
Bashford, C. L., Mason.
Berrydale Experiment Gardens, Holland.
Boehringer Brothers, Bay City.
Blake, Wm., Niles.
Blanchard, Mrs. D. A., Portland.
Bragg & Co., L. G., Kalamazoo.
Brown, D. M., Grand Rapids.
Buskirk, C. M., Big Rapids.
Celery City Nurseries, Kalamazoo.
Central Nursery and Floral Co., Kalamazoo.
Clark, D. H., Holland.
Cole, Levant, Battle Creek.
Coloma Nursery Co., Coloma.
Coryell, R. J., Birmingham.
Cukerski, Wencel L., Grand Rapids.
Culver, O. B., Colon.
Cutler and Downing Co., Benton Harbor.
Daly, T. W., Watervliet.
Dean, Geo. N., Shelbyville.
Dressel, G. L., Frankfort.
Dunham, E. W., Baroda.
Dutton, Chas. S., Holland.
Elliott, Hanson B., Harbor Springs.
Essig, W. W. & Co., Detroit.
Ferrand, E., & Son, Detroit.
Flansburgh, C. N. & Son, Jackson.
Flansburgh-Potter Co., Leslie.
Genesee County Nurseries, Flint.
Gobiel, Patrick, St. Joseph.
Greening Nursery Co., Monroe.
Gustin, C. F., Adrian.
Haines, J. W., Eaton Rapids.
Hamilton, A. & Sons, Bangor.
Hart Pioneer Nursery, Hart.
Havekost, G. H., Monroe.
Hawley, G. A., Hart.
Hawley, H. E., South Haven.
Helmer Farm Nursery, Battle Creek.
Hodges, Ezra and Son, Mayville.
Husted, N. P. & Co., Lowell.
Ilgenfritz, Chas. A., Monroe.
Ilgenfritz Sons' Co., I. E., Monroe.
Jeffrey, James, Sr., Kalamazoo.
Jesse, Harmon V., Stockbridge.
Jones, Ralston S. and Son, Holland.

Kalamazoo Nurseries, Kalamazoo.
Katzenberger, Val, Saginaw.
Kerr, J. W., Montrose.
Kellogg Co., R. M., Three Rivers.
Knapp, W. F., Monroe.
Knight & Son, David, Sawyer.
Lock, Daniel, Union Pier.
Marvin, O. F., Holton.
Maudlin Nursery, The E., Bridgman.
Mayer, M. Jr. Merrill.
McCormick's Nursery Co., Monroe.
Michigan Nursery Co., Monroe.
Miller, Abner, Fennville.
Morrill, Roland, Benton Harbor.
Munson, W. K. & Son, Grand Rapids.
Myers, P. J., Bridgman.
Negaunee Nurseries and Greenhouses, Negaunee.
Nehmer and Sons' Co., Daniel, Ontonagon.
Nelson, J. A. & Son, Paw Paw.
Newell, Reuben, Highland Park.
Pier, Frank D., Leslie.
Pilkinton, S. H., Portland.
Pontiac Nursery Co., Detroit.
Powers, Chas. & Son, Saugatuck.
Prestage, J. G., Allegan.
Prudential Nursery Co., Kalamazoo.
Retz, Mathias, Riverside.
Rokely, J. N., Bridgman.
Rice, Greta B., Port Huron.
Schild, H. J., Ionia.
Singer, W. H., Lapeer.
Smith, Henry, Grand Rapids.
Speyers, Chas. M., Willis.
Spielman Brothers, Adrian.
Stephens, John S., South Haven.
Stoddard, L. H., Kalamazoo.
Stone, John and Son, Hillsdale.
Sullivan and Baker, Adrian.
Taplin, Stephen, Detroit.
Thrasher, C. D., Hamburg.
Tossy, L. F., Detroit.
Tuttle and Lamphear, Paw Paw.
Weston, A. R. & Co., Bridgman.
Whitten, C. E., Bridgman.
Wildemere Gardens, Royal Oak.
Wise, Ralph, Plainwell.
Wolverine Nurseries, Detroit.
Wolverine Co-operative Nursery Co., Paw Paw.

LICENSED DEALERS.

Alferink, Albert, Holland.
Augustine, L. D., St. Joseph.
Beattie, Thos., Detroit.
Bowen A. D., Bear Lake.
Collins, W. E., Fennville.
Crowley, Milner & Co., Detroit.
Davison Nursery Co., Davison.
Dow, H. C., Kibbie.
Drought, Wm., Douglas.
Fair Oaks Nursery Co., Traverse City.
Freyling and Mendels, Grand Rapids.
Grand Rapids Nursery Co., Grand Rapids.
Hall, Frederick T., Greenfield.
Healy, Wm., Bloomingdale.
Herpolsheimer Co., Grand Rapids.
Heyboer, A., Grand Rapids.
Hibbler, Edwin B., Detroit.
Hudson Co., J. L., Detroit.
Kingsbury, Lathrop, Muskegon.
Lohrman Seed Co., Detroit.
Merrill, W. F., South Haven.
Nash, C. C., Kalamazoo.
Pearson Co., D. S., Grand Rapids.
Radewald, Otto, Niles.
Rood, Frank E., Covert.
Smith Mercantile Co., Ira M., Grand Rapids.
Sodus Nursery Co., Sodus.
Strittmatter, Adolph, Detroit.
Sweet, L. H., Carsonville.
Slanker Nursery Co., Benton Harbor.
Trankla, Chas. & Co., Grand Rapids.
Utter, J. J., Bravo.
Walthers' Department Store, Bay City.
Webb, D. S. & Co., Traverse City.
Westgate Nursery Co., The H. L., Monroe.
Winkworth, R. M., Detroit.

LICENSED FOREIGN NURSERIES.

Allen Nursery Co., Rochester, N. Y.
Bogue, Nelson, Batavia, N. Y.
Brown Brothers' Co., Rochester, N. Y.
Bryant Brothers, Dansville, N. Y.
Bryant, Arthur & Son, Princeton, Ill.
Cartwright, I. D., Toledo, Ohio.
Charlton Nursery Co., Rochester, N. Y.
Chase, Chas. H., Rochester, N. Y.
Chase Brothers Co., Rochester, N. Y.
Chase Nurseries, The, Geneva, N. Y.
Costich, Company, G. A., Rochester, N. Y.

Davis Nursery Co., Franklin, Baltimore, Md.
Dreer, Henry A., Philadelphia.
Fairview Nurseries, Rochester, N. Y.
First National Nurseries, Rochester, N. Y.
Fremont Nursery, The, Fremont, Ohio.
Harman Co., M. H., Geneva, N. Y.
Hawks Nursery Co., Rochester, N. Y.
Henby, J. K. & Son, Greenfield, Indiana.
Herrick Seed Co., Rochester, N. Y.
Home Nursery Co., Bloomington, Ill.
Hooker, Wyman & Co., Rochester, N. Y.
Jewell Nursery Co., Lake City, Minn.
Knox & Co., S. H., Buffalo, N. Y.
Masters, G. A., Chicago, Ill.
McGlennon & Kirby, Rochester, N. Y.
North Jersey Nurseries, Newark, N. J.
Pennsylvania Nursery Co., Girard, Penna.
Perry Nursery Co., Rochester, N. Y.
Ringler Rose Co., Chicago, Ill.
Simpson & Son, H. M., Vincennes, Ind.
Standard Nursery Co., Rochester, N. Y.
Stark Brothers' Nurseries & Orchards Co., Louisiana, Mo.
Swain-Nelson Sons' Chicago, Ill.
VanDusen Nurseries, The, Geneva, N. Y.
Weber, Carl H., Greenfield, Indiana.
Western New York Nursery Co., Rochester, N. Y.
Whitney, G. W. & Co., Dansville, N. Y.
Willett & Wheelock, North Collins, N. Y.

Respectfully submitted,

L. R. TAFT,

State Inspector of Orchards and Nurseries.

East Lansing, Mich., June 30, 1911.

TWENTY-FOURTH ANNUAL REPORT

OF THE

EXPERIMENT STATION

OF THE

MICHIGAN AGRICULTURAL COLLEGE

UNDER THE HATCH ACT

FOR THE

YEAR ENDING JUNE 30, 1911.

For members and organization of the State Board of Agriculture in charge of the Station and list of officers, see page 13 of this volume.

REPORT OF SECRETARY AND TREASURER.

The following shows the receipts and disbursements of the Experiment Station for the year ending June 30, 1911.

	Dr.	Cr.
July 1, 1910—To balance	$2,324 52	
July 13, 1910.....received from U. S. Treasury	7,500 00	
Oct. 14, 1910.....received from U. S. Treasury	7,500 00	
Jan. 16, 1911.....received from U. S. Treasury	7,500 00	
April 8, 1911.....received from U. S. Treasury	7,500 00	
June 30, 1911.....license fees, 224 brands com'l fertilizers	4,540 00	
farm receipts	246 23	
from State appropriation, South Haven Experiment Station	2,000 00	
from State appropriation, U. P. Experiment Station	3,000 00	
South Haven Experiment Station receipts	298 39	
U. P. Experiment Station receipts	889 48	
by disbursements as per vouchers filed in the office of the State Auditor General	....	$45,847 36
Balance overdrawn	2,548 74	
Total	$45,847 36	$45,847 36

One hundred seventy thousand seven hundred regular bulletins, twenty thousand special bulletins, eight thousand technical bulletins, thirty thousand circulars and twenty-three thousand reprints have been issued by the Experiment Station during the fiscal year.

DISBURSEMENTS ON ACCOUNT OF U. S. APPROPRIATION.

	Hatch fund.	Adams fund.	Total.
Salaries:			
Director and other administrative officers	$2,120 00	$500 00	$2,620 00
Scientific staff	2,658 85	1,124 55	3,783 40
Assistants to scientific staff	3,459 40	7,227 25	10,686 65
Labor:			
Annual and monthly employees	1,310 87	324 52	1,635 39
Weekly, daily and hourly as needed	987 87	328 54	1,316 41
Publications	90	....	90
Postage and stationery:			
Postage	182 26	4 06	186 32
Stationery	63 64	5 82	69 46
Telegraph and telephone	36 25	....	36 25
Freight and Express	147 31	241 76	389 07
Heat, light, water and power	73 76	....	73 76
Chemicals and laboratory supplies:			
Chemicals	405 29	534 46	939 75
Other supplies	233 64	870 54	1,104 18
Seeds, plants and sundry supplies:			
Agricultural	123 36	11 11	134 47
Horticultural	385 24	....	385 24
Botanical	17 98	141 33	159 31
Entomological	26 81	29 23	56 04
Bacteriological	43 84	103 14	146 98
Chemical	35 52	38 24	73 76
Director's office	3 43	....	3 43
Soils	....	23 10	23 10

U. S. APPROPRIATIONS.—*Concluded.*

	Hatch fund.	Adams fund.	Total.
Fertilizers	$59 49		$59 49
Feeding stuffs		$2 08	2 08
Library:			
Thirty-three Vol. Bericht der deutschen Chemischen	227 84		227 84
One copy Sylloge	48 72		48 72
Binding 245 vols	232 75		232 75
One copy Biochemische Zeitschrift	21 00		21 00
One Chemische Centralblatt	20 00		20 00
One Zeitschrift fuer Hygiene, Vol. 67-70	22 00		22 00
One Set. Genera Insectorum	45 80		45 80
One Vol. The House Fly		5 03	5 03
Other purchases	371 85		371 85
Tools, machinery and appliances:			
New purchases	538 70	6 20	544 90
Repairs	18 50		18 50
Furniture and fixtures:			
One fire proof safe	50 00		50 00
One second hand typewriter	45 00		45 00
One drawing table	24 37		24 37
One Remington typewriter	76 00		76 00
One desk	25 00		25 00
Two chairs	16 00		16 00
One No. 2 L. C. Smith typewriter	81 00		81 00
One hood for Lab. with pipe and fittings complete		67 93	67 93
One stand for thermostat		22 88	22 88
Other purchases	2 50	5 31	7 81
Scientific apparatus and specimens:			
One Torsion balance	35 00		35 00
One camera	21 00		21 00
One Adj. Rheostat	10 00		10 00
One No. 171 polarizer		29 88	29 88
One LLL microscope	67 00		67 00
One Rheostat		24 30	24 30
One Sartorius balance		77 32	77 32
One apochromatic objective		83 26	83 26
One microtome		113 73	113 73
One 5x7 press Graflea micro		110 00	110 00
Two Lab'y incubators		216 00	216 00
One steam pressure sterilizer		180 00	180 00
One Kohlrausch bridge		70 00	70 00
One microscope stand I		104 67	104 67
Other purchases	53 53	1,676 80	1,730 33
Live stock:			
Cattle		50 00	50 00
Swine		367 45	367 45
Small experimental animals	22 50		22 50
Travel expenses:			
In supervision of station work	180 47		180 47
In connection with investigations under Adams act		38 53	38 53
For other purposes connected with station work	313 29		313 29
Contingent expenses	25 00		25 00
Buildings and land	29 47	240 98	270 45
Total	$15,000 00	$15,000 00	$30,000 00

DISBURSEMENTS OF EXPERIMENT STATION MONEYS—OTHER THAN RECEIVED FROM U. S. TREASURER.

Salaries	$3,628 60	
Labor	8,441 84	
Publications	265 27	
Postage and stationery	175 31	
Freight and express	244 46	
Heat, light, water and power	1 50	
Chemicals and laboratory supplies	524 16	
Seeds, plants and sundry supplies	1,009 53	
Fertilizers	24 40	
Feeding stuffs	13 50	
Library	135 78	
Tools, machinery and appliances	98 47	
Furniture and fixtures	30 35	
Scientific apparatus and specimens	97 63	
Traveling expenses	379 79	
Contingent expenses	2 00	
Buildings and land	774 77	
Total		$15,847 36

REPORT OF THE DIRECTOR OF THE EXPERIMENT STATION.

To President J. L. Snyder:

During the year the following publications have been issued by the Experiment Station, viz.:

Bulletin No. 262—Suggestions on Planting Orchards, by O. K. White.

Bulletin No. 263—Fertilizer Analyses, by A. J. Patten, O. B. Winter and C. G. Clippert.

Bulletin No. 264—Second Report of Grade Dairy Herd, by A. C. Anderson.

Special Bulletin No. 54—Revision of Special 51, entitled Spray and Practice Outline for Fruit Growers.

Special Bulletin No. 55—Miscellaneous Analyses, by Andrew J. Patten.

Technical Bulletin No. 6—Lime-Sulphur Sprays. (1) Methods of Analyses (2) Manufacture and Storage by Jas. S. Harris.

Technical Bulletin No. 7—Organic Nitrogenous Compounds in Peat Soils II, by C. S. Robinson.

Technical Bulletin No. 8—Studies of Agglutination Reactions in Hog Cholera During the Processes of Serum Production, by Dr. Ward Giltner.

Technical Bulletin No. 9—How Contact Insecticides Kill, by Dr. G. D. Shafer.

Technical Bulletin No. 10—Influence of the Products of Lactic Organisms upon Bacillus Typhosus, by Zae Northrup.

Technical Bulletin No. 11.—The Fermenting Capacity of the Average Single Cell of Bacterium Lactis Acidi, by Dr. Otto Rahn.

Circular No. 10—Manufacture and Storage of Lime-Sulphur Sprays, by A. J. Patten.

Circular No. 11—Lime for Agricultural Purposes, by A. J. Patten.

Circular No. 12—Tuberculosis in Fowls, by Dr. Ward Giltner.

Press Bulletin No. 24—The Germinating Qualities of Michigan Seed Corn, by V. M. Shoesmith.

During the year nothing has been published from the results of experimental work pursued in animal husbandry. The results of the three years' work referred to in my last report, relative to the use of succulent feed in its relation to wool and mutton production, have not been published owing to the desire to still further repeat the trials, hoping that more data may render the results still more conclusive. An epidemic of disease among the swine has completely thwarted all efforts toward experimentation in this line.

Both the animal and dairy husbandry departments are engaged in carrying forward the up-grading breeding experiments established several years ago. Of course some time must yet elapse before the records of the third generation, as producers, can be established. The dairy husbandry department is conducting investigations relative to the economic production of veal in the dairy herd.

The department of farm and horses continued its work relating to the economic wintering of the farm work horse during the past winter.

The poultry department has continued its tests with three types of farmer's poultry houses and it now seems that further work will be necessary in order to procure positive results.

The time of those in charge of the farm mechanics department has been so completely occupied by instruction work as to render it almost impossible for them to make much progress as regards the lines of investigation work in hand.

A valuable addition in the form of land has been made to the Upper Peninsula Station at Chatham. Six hundred acres of land, with the timber removed has been generously donated by the Cleveland Cliffs Iron Co. for purposes of experimentation and demonstration. This comprises the section on which the town of Chatham is located with the exception of forty acres which forms a part of the town site.

As this property adjoins the present farm of 160 acres diagonally and as it consists of the choicest land in Upper Michigan, the possibilities of developing a model farm are apparent under proper management. It is not intended to develop an experimental farm but rather to establish a model or demonstration farm operated on a commercial basis.

Respectfully submitted,

R. S. SHAW,

Director.

East Lansing, Mich., June 30, 1911.

REPORT OF THE BACTERIOLOGIST.

Director R. S. Shaw:

Dear Sir:—Let me present the work of this division of the experiment station for the past year under the following headings:

(1) General Bacteriology. (2) Soil Bacteriology. (3) Dairy Bacteriology. (4) Pathogenic Bacteriology. (5) Commercial Bacteriology.

GENERAL BACTERIOLOGY.

Under this heading, I desire to submit the paper prepared by Dr. Otto Rahn entitled, "The Fermenting Capacity of the Average Single Cell of Bacterium Lactis Acidi," which is printed elsewhere in this report as Technical Bulletin No. 11. This paper is the result of study and experimental work over a period of several years. While the subject does not deal with any immediate and direct application to agriculture, it is, however, of fundamental interest and use to workers in the field of microbiology, and will doubtless prove essential to the proper development of applied problems.

SOIL BACTERIOLOGY.

This work is under the immediate charge of Dr. Otto Rahn, who has associated with him W. A. Wentworth. The work is in progress, but at this time no results are submitted. Dr. Rahn, however, makes this statement regarding his work:

"The main problem in soil bacteriology is the rôle of microörganisms in the building up of farm land from the two extreme soil types of Michigan; the barren sand of the jack pine plains and peat. The sand is practically free from organic matter, the peat contains hardly anything but organic matter. Both these soil types are very common in Michigan.

It seems reasonable to suppose that more can be learned by following closely the building-up process of a soil than by starting with a good farming soil. This main problem involves the formation of humus and the decomposition and availability of peat compounds as well as the peculiarities of peat as a soil. The experiments were begun in the spring of 1910.

The soils and soil mixtures under study are in large sunken cylinders with open bottom, 4 feet deep and 2 feet in diameter. The cylinders were cropped and treated in various ways. The old idea that peat acts as an antiseptic was easily disproved by a few experiments on bacterial activity in peat. Peptone was decomposed to ammonia, and ammonium salts were oxidized to nitrates without retardation, if sufficient moisture were provided. The so-called "disinfectant qualities" of peat consist probably in nothing more than its great water capacity, and its ready absorption of disagreeably-smelling compounds, such as ammonia, skatol and other products of putrefaction. This is apt to make the layman believe that such decomposition does not take place.

Other problems have been taken up, concerning largely the technic and the reliability of methods in common practice. An extensive statement of the attitude of this laboratory towards soil bacteriology is given in the 13th Report of the Michigan Academy of Science, 1911."

DAIRY BACTERIOLOGY.

Mr. Charles W. Brown, Miss Zae Northrup, and Miss Lulu M. Smith have been occupied with dairy problems during the past year. A brief review of the dairy work conducted by Mr. Charles W. Brown and Miss Lulu M. Smith is added:

"*Butter Investigations.*—An experiment with the keeping qualities of storage butter that was begun almost two years ago has been carried along during the past year by Mr. C. W. Brown and Miss Lulu M. Smith. It comprises a great amount of work dealing with pasteurization and ripening compared with non-pasteurization and non-ripening as factors in lessening the deterioration of storage butter. As this work is now almost complete and as it is to be put out in bulletin form within a short time, a mere mention of it here is deemed sufficient.

Work with Yeasts and Torulae Found in Milk and Butter.—It was noticed that some of the yeasts and torulae isolated during our work with milk and butter have the power of changing the acidity of milk. And as the acidity of butter is associated with and related directly or indirectly to rancidity, physiological investigations along the line of acid production and acid consumption in the metabolism of these yeasts and torulae was thought necessary for a better understanding of some of the changes that occur in storage butter. These investigations conducted by Miss Smith are under way.

Work with Bacterium Lactis Acidi.—A certain amount of work has been done with various strains of *Bact. lactis acidi* with the idea in view of obtaining information valuable to creamerymen, cheesemakers and others who have to do with the carrying along of starters, the ripening of milk and cream and the preparation of milk and whey cultures for dietetic or medical purposes.

Troubles with Off-Flavors in Milk and Cream.—At different places in the state there has been trouble with off-flavors developing in milk and cream. It seems that these off-flavors make themselves evident during the winter and are not noticed during the summer weather. Some attention has been given to these troubles; and in one case there was found in the cream, also in the well water and dust of the barn, a bacillus that, if cultivated in cream at 15° C. or below produces the characteristic off-flavor causing trouble. Precaution was taken to prevent the troublesome organism from entering the cream with the result that the trouble abated, but was not overcome completely."—[C. W. Brown.]

Miss Zae Northrup submits the results of her work upon "The Influence of the Products of Lactic Organisms upon *Bacillus Typhosus*," printed elsewhere in this report as Technical Bulletin No. 10. Miss Northrup is also carrying on some experiments in connection with Dr. G. A. Waterman. The purpose of this work is to secure a better understanding of the production of pure milk. Miss Northrup adds the following concerning this work:

"Dr. G. A. Waterman, former head of our Veterinary Department

and now manager of a large dairy farm near Ann Arbor, this past year has given our laboratory the privilege of working out certain bacteriological problems concerning pure milk in connection with milk produced under varied conditions on his farm. Much valuable data have been obtained and will be compiled later."

PATHOGENIC BACTERIOLOGY.

The agglutination work of Dr. Giltner's which has been conducted here for two or three years past in connection with the Dorset-Niles serum production has been completed, and the results appear elsewhere in this report, as Technical Bulletin No. 8.

Contagious Abortion.—This disease is now receiving special attention from Dr Giltner. The following general remarks from him may be of interest at this time:

"The work with infectious abortion of cattle progressed very slowly until recently. We have succeeded in isolating in pure culture from the exudate and cotyledons of an aborting cow the bacterium described by Bang, McFadyean, MacNeal and others as occurring in epizoötic abortion. The cultural as well as morphological characters of this organism have been well described in the literature and need no repetition here. In the case from which we secured our pure culture we were also fortunate in securing material in the shape of a fetal cotyledon and a fetal and maternal cotyledon attached, sections of which stained in hematoxylin and eosin show characteristic clumps of the *Bact. abortus.* Immunization experiments have been started with guinea pigs and heifers, but a report of this work should be delayed.

The treatment of abortion in practice is receiving attention and certainly demands it if we may judge from the reports of the disease that come to us. The post-abortion treatment of cows, in order to eliminate the organisms from the genital organs and passages and prevent their spread, is a serious and difficult matter. Disinfection of the uterine or even vaginal mucosa is impossible by the use of any disinfectants in solutions weak enough to insure against injury to these tissues. In your report of the preceding year is given an account of the use of lactic cultures in this connection. In this year's work we have used the ordinary lactic organisms and Bact. bulgaricum in whey cultures. At your suggestion, we have also used the whey recovered from milk curdled by these organisms. As to the relative merits of these methods, we may say that whey is superior to lactose broth as a medium for these organisms and that a much higher (two or three times) degree of acid is secured by employing the whey from milk curdled by these organisms, but this higher degree of acidity is objectionable in view of the fact that it terminates the existence of the lactic organisms.

The aim of these operations is to establish a lactic flora on the genital mucosa with the result that the abortion bacteria and other objectionable bacteria will be overcome and not permitted to reappear. It is true that this is merely a hypothesis, but a very reasonable one, and is fortified by favorable clinical experience. We have approached the subject from the experimental standpoint in the following manner: A study of the normal and abnormal (under conditions of abortion and sequelae) flora of the genital passages has been instituted. This is to be followed

by a study of the flora after treatment with lactic cultures. Mr. Knopf has ably assisted in this work, and it bids fair to be of considerable moment, but has not progressed far enough to warrant a more extended report.

The study of infectious abortion is complicated by the (supposed or real) presence of another venereal disease, viz., granular vaginitis. This disease has been studied in Europe especially by Ostertag, who claims the etiologic factor a streptococcus, embedded in the granules, and by Williams of Cornell, and Wills, State Veterinarian of New York. A careful description of this affection is included in Williams' Obstetrics, and need not be repeated here. We have found in a herd of Jerseys at Dryden and several herds of Holsteins at Howell and Chilson as well as in both college herds, a condition that answers the description of this disease. In one of the herds at Howell, the lactic treatment was adopted by the owner under our direction. It is too early to report on the results. Infinite patience must characterize the investigation of these troubles. We hope by our studies to at least be ever ready to adopt any measures suggested as valuable by others more competent or perhaps more favorably situated than ourselves in the conduct of this very expensive work. A further discussion occurs under the abstract on "Granular Vaginitis in Cattle."—[Ward Giltner.]

Miscellaneous Diseases.—In addition to the experimental work conducted, Dr. Giltner has been interested in several diseases which have broken out in this state, and which he has studied more or less. A review of this work follows:

"*Infectious Anemia in Horses at Watersmeet, Michigan.*—At the request of Mr. Hinds, President of the State Live Stock Sanitary Commission, I visited Camp No. 15 of the Bonifas Lumber Co., six miles west of Watersmeet in the northern peninsula. I arrived at the Camp September 1st, 1910.

There were about ten teams and a driving mare housed in two log barns. They were in charge of Mr. Richard Shier apparently a very intelligent and capable superintendent. He had been in charge only since spring, and had worked the teams probably rather severely, but they were in good working condition. The stables were being refitted with hewn log floors.

The horses had been watered from the nearby river which had received the sewage from the camp. Water had recently been supplied from a well. On the whole, the surroundings were unobjectionable. The timbered land that was the field of operation was almost exclusively high land. There must have been some marsh land for swail grass was being cut for the horses.

The disease had begun in June and had resulted in eleven deaths. Not half of the teams in the camp were able to do a good day's work. When they returned from work at night, only one team appeared in full vigor. The others looked tired, the facial expression was dull and the ears drooping.

Two veterinarians had treated the horses for influenza, and the horses were not benefited. A third veterinarian, Dr. Edward Fitzsimmons of Ironwood, Michigan, pronounced the disease swamp fever. The nature of his treatment was not revealed to the writer.

The symptoms were moderate, irregular fever, great weakness, uncertain gait, polyuria, pale or yellowish mucosae, and more or less oedema of the dependent parts. Throughout the disease, the horses stood and ate listlessly of both hay and grain. At the last, they became too weak to stand.

The animals usually died within a week or two after they were considered sick, but I suspect the course of the disease was hastened by the treatment for it is known that horses suffering from infectious anemia stand antipyretic and cathartic treatment badly.

We were informed that this disease or one similar to it had been seen in at least three other places in the Northern Peninsula, and residents of Wisconsin, south of Gogebic county claimed that they had seen it in their state.

We are not familiar enough with the disease to make a positive diagnosis. In short, we know of nothing specific upon which a diagnosis may be based, but the history of the affection and the symptoms strongly suggest Infectious Anemia.

(See report of Bacteriologist for year ending June 30, 1909, for account of this disease in the Northern Peninsula.)"—[Ward Giltner.]

A Disease of Cattle near Ubly, Huron Co., Mich.—"The State Live Stock Sanitary Commission requested the laboratory to send someone to meet the President of the Commission at Ubly to determine the cause and nature of a disease of cattle reported by the local health officer, Dr. MacGregor, to be very prevalent in this section.

August 2, 1910, I met Mr. Hinds, and together with Dr. MacGregor we visited a number of farms where cattle were reported affected with this disease.

The lay of the land is pretty much the same in this region—a fairly level, fertile area with numerous wild and low places. It has been under cultivation not much longer than ten years. The cattle examined by us showed the influence of Short-horn stock and were above the average in general condition.

Mr. Frank Penuski's herd showed the most extensive lesions about the head. On the external lateral surfaces of the mandibles, on the cheek, in the intermaxillary space and even on the side of the neck were severe lesions produced by an irritant applied by a neighboring farmer who is also a registered veterinarian. The skin was badly blistered, but aside from this there were subcutaneous swellings, hard and knotted, not attached to the bone and also fluctuating swellings filled with pus. We opened one of these abscesses and evacuated a quantity of odorless, thick, light yellow, viscid pus.

We saw the cattle of other farmers showing similar cutaneous lesions, presumably caused by blistering. In addition to this, Mr. Bukowski had one cow that was rather thin in flesh, had an abscess posterior to the left carpus and an affection of one-half of the udder resembling a neoplasm of some description. This cow was killed. A foul-smelling, yellowish pus was evacuated from the abscess, and portion of the udder retained for microscopical examination. The intermaxillary region had been blistered three or four weeks before, but showed nothing more than a thickening of the skin. The cow was otherwise normal.

We visited the home of Mr. Sparling, the author of the wide-spread blistering. His own cattle had not escaped the application of this irritant, the nature of which could not be revealed. Some of these cattle showed small, cutaneous swellings, just above the dew-claws. Mr. Sparling assured us that this was the most dire plague that ever visited man or beast, attacking as it did all cattle, regardless of age, and involving any portion of the skin or internal organs. Cattle that died showed violent purging. (Dr. MacGregor was aware of the fact that Mr. Sparling bought inordinate quantities of croton oil.) He had seen the udder frequently affected and classified the case examined by us as an example of this plague which he termed muscular tuberculosis, being different from tuberculosis as we are familiar with it. He recognized three distinct diseases of cattle as very prevalent in the neighborhood, viz., tuberculosis, actinomycosis and muscular tuberculosis.

Muscular tuberculosis manifested itself as a swelling in the intermaxillary space the size of a hickory-nut usually, but attaining the size of a hen's egg. This swelling was in the region of the submaxillary lymph glands. Mr. Sparling treated cattle at such times as he could spare from his farm work, usually after supper. His rate was three dollars up to twelve head, and twenty-five cents for each additional animal. Judging from the herds seen by us, close to 100 per cent of the cattle in herds treated were affected. It was difficult for us to make any valuable and reliable observations, on account of the treatment to which the animals examined by us had been subjected. Other duties prevented our making an investigation of diseased cattle that had not been treated. Dr. MacGregor was satisfied that there was some disease in the cattle of the region that required the careful work of a diagnostician to determine.

Examination of material at laboratory:

Pus from cheek of Penuski's cow: Odorless, light color, viscid.

Microscopical: No bacteria, very few cells (polynuclear leucocytes), much fibrin.

Inoculation into bouillon and agar gave no growth.

Guinea pig inoculated 8-3-10 subcutaneously.

Pus from abscess on carpus of Mr. Bulsowski's cow: Bad odor, not viscid, yellowish.

Microscopical: Many bacteria, micrococci mostly in pairs and tetrads about .5 mikron in diameter; many pus cells.

Gross appearance of the diseased udder suggested a sarcoma.

Microscopic examination proved the tumer to be a soft fibroma (fibrosarcoma)."—[Ward Giltner.]

"*Malignant Catarrh of Cattle.*—We were requested to investigate a supposed outbreak of malignant catarrh of cattle on the farm of Mr. W. N. Park, Sunfield, Mich., on May 15, 1911. On April 13th a grade Short-horn cow had lost her calf presumably as a result of injury inflicted by another cow. This cow retained her afterbirth and developed a serious discharge from eyes and nose with a fatal termination in about 24 hours.

The second case, which I attended, was a red poll grade cow. The owner associated a purulent discharge from eyes and nose with the

former cow and was suspicious of a contagious causation. Hence we were called to investigate.

The farm was well drained with no bottom or swamp land. The cows had been on pasture only a short time, and had been out only a few nights. The weather was very mild. They had access to a thinly-wooded tract that had been pastured for many years. The cow stable was in a low dark basement with a wet dirt floor saturated with urine. Bedding was plentiful, and the place was not exceptionally dirty. There had never been any similar cases on the farm before, and no record of any in the neighborhood. There were three other apparently healthy cows on the place.

The local veterinary was treating the case with febrifuges (probably aconite) and eye washes. The cow was suffering from several degrees of fever, had had chills and even shivered at the time in spite of warm blankets and a warm atmosphere. There was considerable fibrino-purulent discharge from eyes and nose of very yellowish color. She was still kept in the barn basement with little or no ventilation.

The owner did not expect her to live the day out, so was willing to have her killed. He was afraid of the discharge. The trouble had existed only three days at the beginning of which a veal calf had been taken from the cow in the morning, and at night she gave no milk and showed symptoms of sickness. What the course of the disease might have been can only be judged by other cases. Probably she would have lived only a few days.

She was killed by ordinary butcher's method after a considerable walk across the fields accomplished with difficulty. Autopsy showed the udder containing some secretion, teats very sore and skin badly fissured, internal organs uniformly normal. The eyes showed catarrhal conjunctivitis. The sinuses of the head were apparently healthy, and contained no discharge. The nasal mucosa was slightly congested, there was a slight amount of purulent exudate on the laryngeal and pharyngeal mucosa. The brain showed the results of the method of killing. The carcass was burned.

The post-mortem did not account for the severity of the disease. Since we do not understand the disease at all well, especially its etiology, we can offer no explanation. Had no other cases developed, this might have well been termed a simple catarrh of the upper respiratory passages amenable to treatment. Subsequent developments indicate differently. M. pyogenes aureus was isolated from both eye and laryngeal exudates. An unidentified bacillus was also present.

On the night of our visit, a two-year-old black heifer showed sore teats, with integument cracked and easily peeled off, leaving the sensitive structure exposed. She could not be milked after the next morning when she showed a slight discharge from eyes and nose. She had chills and probably fever. No temperatures were taken. The owner treated her with inhalations of Kreso vapors and nasal irrigations of diluted Kreso. This seemed to lessen the discharge and keep the respiratory passages temporarily open. She rapidly grew worse, could not eat, breathed with difficulty having the mouth open and tongue hanging out. The discharge became thick and yellow. She became blind from opacity of the cornea. Death occurred six days after the onset of the disease.

Autopsy: about 8 hours.

Post-mortem. Emaciation slight, no bloating, skin of teats peeled off easily; conjunctival discharge slight, nasal discharge considerable; nasal mucosa congested and covered with croupous exudate; sinuses open but membrane congested; horns easily detached; horn core greatly reddened; oral, pharyngeal and laryngeal mucosa diphtheritic; trachea, bronchi and bronchiols lined with thick, yellow croupous membrane easily separated as a cast of the tubes. Lungs showed interlobular emphysema; there were numerous sub-epicardial petechiae and ecchymous; cholecyst distended with dark, greenish bile and bile ducts full on section of liver; kidneys congested; spleen normal; rumen about half distended with normal ingesta and only post-mortem changes; reticulum and abomasum same; abomasum greatly congested and slight catarrh of mucosa and slight capillary hemorrhage; small and large intestine same; (blood-stained feces had been passed).

From the croupous tracheal exudate both M. pyogenes aureus and albus were isolated.

On May 30, 1911, in response to a call from Dr. Waldron of Tecumseh, I visited the farm of Mr. Wm. Hogan of Clinton to investigate an outbreak of a disease in steers. Dr. Waldron had pronounced the disease malignant catarrh. The herd affected consisted of sixty western steers bought in the fall of 1910. One steer died shortly after purchase, but no observations were made on the circumstances attending death. At the time of my visit, five steers had died and one was sick. The remainder had been shipped for slaughter, and were in excellent condition.

Dr. Waldron said that he had a few cases of this nature in his practice each year, and usually only a few animals in each herd were affected. It did not appear to be contagious, and there was nothing in the history of the cases that suggested a cause, either immediate or predisposing. The cases occurred at any time of the year. The symptoms were sudden onset, lack of appetite, fever, dyspnoea, swollen conjunctiva, with at first excessive lachrymation, then purulent discharge, opacity of cornea with blindness, nasal discharge of thick, yellowish nature, and death invariably after about one week. No treatment of any value. Catarrh of the abomasum and small intestine, with other stomachs normal found on post-mortem.

The only case left on the farm at the time of my visit was a red poll steer in good flesh. He showed slight purulent discharge from eye, cornea partly opaque, thick yellow nasal discharge slight, breathing slow, regular and slightly labored, diarrhea. An attempt to catch the animal resulted in increased respirations and snorting. A piece of diphtheritic membrane was thus blown from one nostril and secured, before it touched the ground, in a sterile dish. Animal recovered.

A culture of both M. pyogenes aureus and albus was secured from the membrane.

A calf inoculated with bouillon suspension of membrane subcutaneously and treated with portion of the membrane smeared on the nasal mucosa developed only a slight abscess at point of inoculation. A rabbit was killed in 24 hours by intraperitoneal injection of bouillon suspension of membrane and a guinea pig in 48 hours by subcutaneous injection. The only point of note in the bacteriological study is the

presence of M. pyogenes in all cases. We take these organisms to be secondary invaders. The literature is very meager on the subject."—[Ward Giltner.]

Granular Vaginitis of Cattle.—"Granular vaginitis is a venereal disease of cattle manifesting itself by congestion and papule formation in the vulvar and vaginal mucosa. A muco-purulent or blood-tinged discharge may accompany the disease especially after service. What is at present known of this disease in Europe and America is well covered in Veterinary Obstetrics by Williams who is at present investigating the trouble.

It is necessary to differentiate this affection from Bang's epizoötic abortion since it is credited with as many as 50 per cent of abortions in an affected herd. It is also guilty of producing at least temporary sterility or failure to breed and since it is frequently accompanied by cystic and other ovarian troubles, it is believed to induce permanent sterility. It is in connection with abortion and sterility that our attention has been called to this disease in a number of widely separated sections of the state.

After considerable correspondence with Mr. Gilbert Harris, we visited his place at Dryden, October 20, 1910. His herd consisted of 18 Jersey cows, 7 heifers and 6 heifer calves in addition to several bulls. Several abortions had occurred, but they were all associated with probably accidental causation. Failure to breed and a chronic vaginal discharge was the cause of complaint. The following table gives a good understanding of the condition of the herd as regards age, number of calvings, condition of vagina (or vulva), and pregnancy.

Number.	Age; years.	No. of calvings.	Vaginitis.	Pregnant; months.	Remarks.
1	7	5	—	3	
2	7	5	—	3	
3	3	1	+	—	Whitish discharge; does not breed.
4	4	2	+	—	Slight discharge; does not breed; retained afterbirth 16 months ago.
5	6	4	+	6	
6	6	4	+	—	Does not breed.
7	10	7	+	5	
8	8	5	+	—	Aborted accidental (?); does not breed.
9	6	4	+	—	Aborted accidental (?); does not breed.
10	2	0	Slight	+	
11	16	12	Very slight.	+	
12	7	5	—	+	
13	3	0	++	—	Aborted first calf; does not breed.
14	2	0	+	—	Aborted at nearly full term; not breed well.
15	2	0	+	+	
16	2	0	++	—	Aborted 4 months calf; not bred since.
17	2	0	+	—	Not bred.
18	17	14	?	+	
19	1	0	+	+	
20	1	0	+	+	
21	1	0	Very slight.	—	
22	1	0	++	—	
23	1	0	Slight	—	
24	1	0	+	+	
25	1	0	?	—	

The six calves examined showed as follows:

Number.	Age; months.	Vaginitis.
1	8	+
2	5	+
3	2-3	—
4	2-3	—
5	5	+++ congested.
6	4	+

A summary of the condition of the herd shows that of the 31 animals examined, 2 calves 2 to 3 months old, and 3 cows 7 years old with perfect records were free from vaginitis; two were doubtful, and four were slightly affected; all the others ranging in age from four months to 16 years were affected. The calves, yearlings and two-year-olds were not affected.

The greatest trouble appeared to be in getting the animals to breed and in overcoming vaginal discharge. The treatment had been varied, consisting in very weak carbolic acid solutions, sodium chloride, potassium permanganate solutions and solutions of white oak bark. All of these injections sooner or later seemed to produce irritation and did not overcome the discharge. Williams discusses the great difficulty in overcoming the trouble, and we have tried to profit by his experiments. We recommend that the tail, buttocks and external genitals be washed daily in 1-1000 solution of mercuric chloride, which was to be used also freely in the stable. The vagina was to be flushed with several quarts of 0.75% compound cresol solution (or lysol) and the vulva with 2% solution of same several times each week.

The owner reported that he sold a great many of his cows after fully explaining the nature of the trouble to the buyer. In fact, we received a letter from one of the buyers who stated that the condition still persisted in the animals purchased. The treatment applied to the animals retained was reported as fairly successful.

On October 25, 1910, we made an examination of the college herds, both dairy and beef. In the dairy herd 45 cows (and heifers) and 3 calves were examined. The accompanying table gives the condition in this herd.

College Dairy Herd. October 25, 1910.

Number.	Age.	Breed.	Vaginitis.	Pregnant.
1	2 years	Brown Swiss	—	+
2	10+ years	Brown Swiss	—	— aborted.
3	10+ years	Brown Swiss	+	+
4	3 years	Brown Swiss	++	+ 7 months.
5	3 years	Holstein	+	+ 8 months.
6	4 years	Holstein	++	+ 7 months.
7	3 years	Holstein	+ very slight.	+ 8 months.
8	3 years	Holstein	+ slight.	+ 7 months.
9	10 years	Jersey	—	+ 7 months.
10	2 years	Jersey	++	+
11	6 years	Jersey	+	+ 7 months.
12	3 years	Jersey	—	+ 8 months.
13	3 years	Jersey	?	+ 7 months.
14	3 years	Jersey	—	+ 7 months.
15	3+ years	Jersey	—	+ 7 months.
16	5-6 years	Ayrshire	++	+ 7 months.
17	4 years	Guernsey	++	+ 7 months.
18	6 years	Guernsey	+	+ 7 months.
19	6-7 years	Guernsey	++	+ 1 month.
20	4 years	Guernsey	+ slight.	+ 6 months.
21	3 years	Guernsey	— puffy	— Just calved.
22	2 years	Jersey	+	+ 6-7 months.
23	2 years	Jersey	++	+ 6 months.
24	2 years	Jersey	+ puffy	+ 8 + months.
25	2 years	Jersey	+ puffy	+ 8 + months.
26	8 years	Holstein	+	+ 8 months.
27	7-8 years	Holstein	+	+ 4 months.
28	7-8 years	Holstein	—	+ 8 months.
29	7-8 years	Holstein	++	+ 8 months.
30	3 months	Holstein	+	+ 2 months.
31	2 months	Holstein	— puffy	— Just calved.
32	2 months	Holstein	+	+ 8 + months.
33	4 months	Gr. Holstein	— puffy	— Just calved.
34	5-6 months	Gr. Holstein	+	+ 7 months.
35	4 months	Gr. Holstein	+	—
36	2 months	Gr. Holstein	++	+ 2 months.
37	3 months	Guernsey Holstein	++	— Aborted twice.
38	4 months	Grade Guernsey	+ puffy	— Just calved.
39	7-8 months	Grade Guernsey	++	+ 7 months.
40	3 months	Grade Guernsey	—	— aborted.
41	2 months	Grade Guernsey	— puffy	— Just calved.
42	2 months	Grade Holstein	+ puffy	+ 8 + months.
43	2 months	Grade Holstein	++	+ 7 months.
44	2 months	Grade Holstein	+	+ 7 months.
45	2 months	Grade Holstein	+	+ 7 months.
Calves:				
1	5 months	Brown Swiss	+	
2	2 weeks	Guernsey	—	
3	1 month	Holstein	—	

On the following day there were examined 16 cows (and heifers) and 3 calves in the beef herd. The accompanying table gives the condition in this herd.

About 66 per cent of the cows and heifers were affected. Only one of the six calves was affected. It is very noticeable that just before or after calving the vulvar mucosa is considerably swollen and consequently the papules may be present but not apparent. This probably applies to a considerable number of the negative cases recorded. In both of these herds there is considerable abortion caused, as we believe, by Bact. abortus (Bang). There is also an occasional complaint

on account of failure to breed. For two years the lactic acid treatment has been applied to all cases requiring treatment of the genital passages. We cannot determine the amount of damage caused by the "Granular Vaginitis" in these herds.

In the work that we are doing with pure cultures of Bact. abortus (Bang) it was found that one of the heifers, the one that is being immunized, shows lesions of "Granular Vaginitis" very markedly, while the check is free from any lesions of this disease. We may eventually profit by this condition.

Beef Cattle. College Herd. October 26-10.

Number.	Age.	Breed.	Vaginitis.	Pregnant.
1	2 years	Short Horn	+	— Just calved.
2	Rose Bud	Short Horn	—	— Bought recently.
3	Belle	Short Horn	+	—
4	Heifer	Short Horn	+	+ 8 months.
5	(16A)	Short Horn	—	+ 3 months.
6	3 years	Angus	—	+ 3 months.
7	7-8 years	Angus	—	+ 7 months.
8	4 years	Hereford	—	— Just calved; bought recently.
9	Juanita, 4-5 years	Short Horn	—	— Treating—vulva all slime.
10	Snowbird, 4 years	Red Poll	—	— Aborted; treating.
11	Jane Bright	Short Horn	+	+ 6 months.
12	Hudson, 5-6 years	Short Horn	+	+ 4 months.
13	Rose, 4 years	Short Horn	+	+ 8 months (aborted first two weeks)
14	Airdrie, 5 years	Short Horn	+	+ 6 months.
15	Pansy (old)	Red Poll	+	—
16	Sold	Scrub	—	+ Alkaline vulva.
Calves:				
1	6 months	Angus	—	
2	7-8 months	Short Horn	— (?) slight	
3	2 weeks	Hereford	—	

On January 21st, 1911, we visited Chilson, Michigan, on account of other trouble but incidentally were able to examine a number of herds for "Granular Vaginitis."

The herd of Mr. J——— R———— consisted of 10 registered and grade Holsteins and one calf 2 to 3 months old. The latter was not affected. The records on the others are as follows:

Name.	Age.	Vaginitis.	Remarks.
Purity	4 years	+	One calf at 3 years old; bred.
Gypsy	8 years	+ discharge	Bred yesterday; vulva swollen.
Kit	6 years	+	Bred; 3 calves.
Aggie	10 years	+ discharge	Bred 2 days ago; lost last calf at 7 months.
Jenny	6 years	+	Three calves; bred 3 weeks; first affected.
Primrose	6 years	+ discharge	Bred 3 weeks; 3 calves; lost one.
Goldine	7 years	++ congested	Bred 3 weeks; 4 calves.
Pauline	3 years	++	Bred 3 weeks; one calf.
Goldine III	18 months	Slight	In calf 5 months.
Wayne	2 years	Slight	Bred 2 weeks.

The trouble in this herd seemed to have been introduced into other herds, but it is very difficult to trace this affection from herd to herd.

Mr. Ed. McI——— had 4 cows all affected, but had no trouble.

Mr. M——— H———— with Grade Holsteins, had only 4 out of 9 affected. No trouble was reported in this herd.

Mr. H——— S———— had 7 or 8 cows which could not be secured for examination. One only was examined and found affected. The owner claims to have been infected from the herd of J——— R———.

Mr. J—— S———— had 11 Short-horns. Of these, 5 were affected, one being a ten-year-old, the others heifers.

Mr. A——— S———— had 4 Short-horns, one of which was affected.

At Howell on April 8th, 1911, we examined a herd of registered Holsteins. Our attention was called to this herd because of the fact that a large number of heifers had failed to breed although two bulls had been used, one of which had an excellent record for potency. Out of 22 cows examined, 3 were not affected at all, or at least very slightly; 4 were affected slightly; 6 were affected to a greater extent, and 9 were badly affected. Of the 14 yearling heifers, one was in heat and the vulva was swollen so that no papules could be seen. Three were slightly affected; 6 were affected to a greater extent, and 4 were badly affected. Eight calves about 4 months old were all slightly affected.

On an adjacent farm belonging to the same owner, there had been no trouble with breeding. All of the cows that were examined here showed nothing more than slight affection. One out of 5 calves about 4 months of age was slightly affected.

The lactic acid treatment was adopted in the affected herd, and its application was successful. We are not yet acquainted with the results of the treatment. We hope to keep in touch with this disease, but have no plan outlined for investigation."—[Ward Giltner.]

Avian Tuberculosis.—"Conversation and correspondence with Mr. J——— R————, of Chilson, Mich., resulted in his sending us by express a dead hen. Autopsy of this hen showed extensive tubercular lesions of liver, spleen and intestine.

A visit to Chilson, January 21, 1911, disclosed the fact that Mr. R———— had lost by death and slaughter on account of sickness probably 150 birds. There were about that many remaining, and many of them showed signs of tuberculosis, such as pale comb and wattles, emaciation, ruffled feathers and general lack of tone. A barrel in the yard contained the frozen carcasses of a number of tuberculous hens. An excellent specimen of the disease affecting the lung was secured.

It was found that several neighbors had lost occasionally a few chickens from a chronic wasting disease. On one farm, a Plymouth Rock hen that had died the previous night showed a few tubercles in the liver and intestinal wall. I learned that, on the farm of Mr. R——— about 10 years previous (when Mr. R———'s predecessor sold the farm), a disease was affecting the flock and that diseased birds had been sold about the community. A neighbor claimed that he had at that time lost nearly all his flock of a chronic disease. It was found that tuberculosis was not infrequent in women, farmers' wives, in this community.

Our knowledge of avian tuberculosis and its control and eradication was very limited and purely academic. We decided that, on account of the limited value of the individual birds and of the impossibility of detecting the disease in the living birds by any means known to us, it

was best to advise the slaughter of the entire flock and the disinfection of the premises. The following spring might safely permit of the introduction of a new flock.

We wished to avail ourselves of the opportunity offered to acquire some data on the subject of tuberculosis in birds. It was, accordingly, arranged with Mr. R——— to have all his chickens slaughtered and picked ready for market, reserving only about 20 of those visibly affected with the disease. We then agreed to make a careful autopsy of each bird and let the healthy ones pass for food. Mr. H. L. Kempster of the poultry department was invited to join us in the examination, and in the succeeding work. His experience as a poultryman was of great value to us in these studies, and he has our thanks for his kind coöperation.

In attempting to decide what standard might be used in determining the safety of these carcasses for food, we had only the U. S. Government meat inspection regulations to guide us. These regulations relate to the inspection of mammals only, chiefly cattle and swine, and we decided that we were dealing with an entirely different proposition. To be sure, any standard of inspection of tuberculous chickens must be arbitrary until it can be based on a wider knowledge of the disease than we now possess. We, therefore, decided to pass only those showing *no lesions whatever*. Assuming that avian tuberculosis is infectious to humans, one can readily see the danger in dressing the carcass of a tubercular bird especially to the housewife. The tubercle bacteria are exceedingly numerous in avian tubercles, and the hands of the operator might easily become badly contaminated, followed by the contamination of the lips or food substances, or utensils that might reach the mouth before the intervention of any sterilizing process.

Out of 143 birds examined, 48 were found diseased. The following tabulation shows the distribution of the gross lesions detected in a more or less hasty examination:

Liver only, 18 cases, 37.5 per cent.
Intestine only, 13 cases, 27.08⅓ per cent.
Liver and intestine, 7 cases, 14.58 1-7 per cent.
Liver and spleen, 5 cases, 10.41⅔ per cent.
Intestine, liver and spleen, 3 cases, 6.25 per cent.
Intestine and spleen, 1 case, 2.08⅓ per cent.
Spleen only, 1 case, 2.08⅓ per cent.
Forty-eight cases, 100.00 per cent.

Of the 48 cases:
The liver was involved in 33 cases or 69 1-12 per cent.
The intestine was involved in 24 cases or 50 per cent.
The spleen was involved in 10 cases or 20 5-6 per cent.

It does not follow from these tabulations that there were not other tissues affected. We know that the mesentery was affected in many cases. The viscera were removed through as small a vent about the cloaca as possible, consequently the lungs and kidneys were not seen.

The passing of any of the birds without a more extended examination of the organs may be open to criticism. We will not discuss that. It is of interest to note that the birds were nearly all in very good condition, even fat. Only two or three showed active ovaries.

About the second week in February, we received 19 chickens that

TABLE I.—*Normal white leghorns from M. A. C. poultry department.*

Number of bird.	Feb. 22, 4 p. m.	Feb. 23, 9 a. m.	4:30 p. m.	Feb. 24, 9 a. m.	4:30 p. m.	Feb. 25, 8 a. m.	Injected 9 a. m.	10 a. m.	11 a. m.	1:30 p. m.	3 p. m.	4 p. m.	5:30 p. m.	8:15 p. m.	Injected 9 p. m.	Feb. 26, 9 a. m.	10 a. m.	11 a. m.	2:45 p. m.	3:30 p. m.
728	108.7	107.9	106.8	107.4	107.7	107.2	0.1cc.*	108.3	107.6	108.3	107.5	108.6	108.5	109.5	......	107.7	108	107.7	108	108
166	107.6	107.4	107.5	107.3	107.8	107.3	0.5cc.*	105.7	106.9	107	107.7	107.3	108.3	105.1	n. b.	104.5	104	103.3	104	103.7
676	106.8	107.2	107.5	107.5	106.6	107	......	107.4	108	107.2	107	106.7	......	104.8	1 cc.	107.1	107	107	107	106.5
484	106.4	107.5	106.4	106.8	107.7	107.2	2 cc.	107.1	107	107.6	107.6	107.4	106.8	106.2	......	107	108.2	107	107.1	107.5
619	107.5	107.6	107.7	107.6	107.3	107.8	......	107.7	107.2	107.4	107.5	106.6	......	106	1 cc.	107.6	107.3	107.5	106.3	107
736	107.4	107.4	107	107.7	107	107.2	......	107.3	107.7	107.4	107.6	106.4	......	105.8	1 cc.	107.1	107.6	107.6	107	106.7

*This tuberculin was diluted 10 times with 0.5 per cent carbolic acid.

N. B.—This bird was affected with a very sore comb as a result of fighting and the condition was aggravated during the test. Death occurred next day.

TABLE II.—*Normal and tuberculous birds from flock at Chilson.*

Number of bird.	Feb. 22, 4 p. m.	Feb. 23, 9 a. m.	4:30 p. m.	Feb. 24, 9 a. m.	4:30 p. m.	Feb. 25, 8 a. m.	Injected 9 a. m.	10 a. m.	11 a. m.	1:30 p. m.	3 p. m.	4 p. m.	5:30 p. m.	8:15 p. m.	Injected 9 p. m.	Feb. 26, 9 a. m.	10 a. m.	11 a. m.	2:45 p. m.	3:30 p. m.
806	106.4	107.9	107.5	108.4	105.4	108.6	......	107.2	107.4	107	107.2	106.2	......	105.6	1 cc.	106.5	107	107	106	107.6
102	107	107.4	107.7	107.4	108	107.6	......	107.4	107.4	106.8	107	106.8	......	106.2	1 cc.	107.4	108.2	108.2	107	107.3
20	107.8	107.3	107.6	107	107.1	107.8	0.1cc.*	107.4	107.4	107	107.2	107.4	107.8	106.9	......	106.8	107	107	107.3	106.8
455	108.2	107.5	107.5	107.7	106.4	107.5		107.4	107.5	106.7	107	106.7	......	106.1	1 cc.	107	107.2	108	106.9	106.6
731	107.6	107.1	107.7	108.4	108.5	107.3	......	107.2	106.6	106.9	107.5	106.5	......	106.8	1 cc.	107	108.4	106.6	107.2	107
234	108.4	107.6	107.8	107.5	107.6	107.4		107.7	108	107.2	106.8	107	......	105.5	1 cc.	107.7	108.7	108.2	107.9	106.8
159	109.5	108.4	108	107.8	108.2	107.8	5 cc.	107.6	106	107.3	107.5	108.3	107.5	106.6	......	107	107	107	107.2	107.4
137	109	108.5	108	108.6	107.6	107.8	......	107.6	107	107.6	107.3	106	......	105.1	1 cc.	108.7	108.4	107.2	107	107.2
The birds registered above proved normal on post mortem; the following were tubercular:																				
19	108	107.5	......	108.5	107	107.2	0.2cc.*	107.4	107.6	107.3	107.9	108.9	109.3	107	......	105.6	107.6	107.4	107.6	107.5
369	107.2	107.8	107.7	108.4	107.2	107.2	......	107.5	107.2	108.3	107.4	107.4	......	107.2	1 cc.	108.2	108.3	108	108	107.6
258	107.6	107.9	106.4	107.6	108.1	107.7	0.5cc.*	107.5	107.6	107.6	107	107.4	105.6	106.6	......	106.9	107.1	108.2	108.3	107.7
963	107.4	107.7	107.2	107.4	107.8	107.7	......	107.9	107.3	107.2	107	107.2	......	105.8	1 cc.	107.3	107.3	107.3	107	107
560	108.8	108.4	107.6	103.4	108.4	107.5	......	107.9	107.8	108	107.9	106.8	......	106	1 cc.	107.4	108.2	108.1	107.5	106.7
895	107	107.4	107.7	107.5	107	107.2	1 cc.	107	107.2	107.5	108.2	108.7	108.6	107	......	107	107	107	106.5	107
643	107.4	107.4	107	107.6	105.5	105.7	2 cc.	107.3	105.2	107.3	105.8	105.2	106.1	107	......	107	108.5	107	107	105.3
74	108	107.8	106.4	107.6	105.9	107.6	......	107.6	107.4	108	107.6	107	......	107.1	1 cc.	107.7	108.3	107.9	107	105.8
457	108.2	107.5	107.4	107.6	107.7	107.6	......	105.7	107	107	106.9	107.6	......	106.2	1 cc.	106.8	107.6	107.4	105.8	106.6
30	107.6	107.7	107.5	107	107.4	107.2	......	106.3	105.1	107.1	107	106.2	......	106.4	1 cc.	109.5	107.6	107.6	107.8	108

*This tuberculin was diluted ten times with 0.5 per cent carbolic acid.

had been reserved as the most probably affected. One of them died shortly after receipt and showed, on autopsy, tubercular liver, spleen and intestines. We decided to try the tuberculin test on the remainder. Six healthy white leghorn hens were introduced from the college flock as checks. The Government (B. A. I.) tuberculin was used. Tables I and II show the results of the tests on both the normal birds from the college flock and the normal and tubercular birds from Chilson. Initial temperatures were taken on Feb. 22, 23, 24 and at 8 a. m., Feb. 25th. Three normal college birds were then injected with 0.1 cc. and 0.5 cc. of tuberculin diluted ten times with 0.5 per cent carbolic acid respectively, and one with 2 cc. of undiluted tuberculin. Also six of the Chilson chickens were injected, one with 0.1 cc., one with 0.2 cc., and one with 0.5 cc. of diluted tuberculin, and one with 1 cc., one with 2 cc., and one with 5 cc. of undiluted tuberculin. The temperature of these birds was then taken throughout that day and the following. The remaining birds were injected at 9 p. m. on Feb. 25th with 1 cc. each of undiluted tuberculin. The injection was made into the pectoral muscles in all cases.

The results confirm the work of Ward in this connection, and show the inapplicability of the tuberculin test with chickens. Ward obtained similar results with avian tuberculin, i. e., tuberculin prepared from avian tubercle bacilli.

There is a greater variation in the temperatures of the normal birds than in the tubercular. Absolutely nothing can be deduced from these records that will serve as a clue to further work along this immediate line of investigation. The problem must be approached from a different angle.

Autopsy records showed the first eight chickens in Table II to be free from gross lesions of tuberculosis.

No. 19 showed emaciation—liver, intestine, spleen affected.
No. 369 showed emaciation—liver, intestine, spleen affected.
No. 258 showed emaciation—liver, intestine, spleen affected.
No. 963 showed intestine slightly affected.
No. 560 showed liver, intestine, mesentery, ovary affected.
No. 895 showed intestine and liver affected.
No. 643 showed emaciation; liver, intestine and spleen affected.
No. 74 showed emaciation; intestines affected.
No. 457 showed emaciation; liver affected.
No. 30 showed emaciation; liver affected.

Of these cases:

Four or 40 per cent. showed liver, intestine and spleen affected.
Two or 20 per cent. showed intestine and liver affected.
Two or 20 per cent. showed liver only affected.
Two or 20 per cent. showed intestine only affected."—[Ward Giltner.]

A Disease of Sheep in Clinton County.—"Dr. Gohn has reported losses of ewes advanced in pregnancy for a number of years. Almost without exception, the ewes have carried twin lambs. The mortality in affected cases has been practically 100 per cent, but only a small percentage of a flock as a rule has suffered. The sick animals lose their appetite, persist in a recumbent attitude with the head drawn to one side, as in milk fever in cows, and the neck muscles are tensely con-

tracted. The head cannot be placed in any other position without considerable force. As the disease advances, the sheep can not, or at least will not stand. Constipation is present. Many may injure the cornea and conjunctiva while struggling. Death usually occurs in a week. It is usually found that these flocks are subjected to a diet in which succulent feed and a proper grain ration is conspicuously absent, and where coarse fodder forms the bulk, or the entire ration. Even where clover hay is used, it is usually very coarse and woody. Bean vines are very frequently used in excess, and Dr. Gohn has suspected them of being responsible for the trouble in large part. It is also found that the sheep are too closely confined, usually having only a small lot for exercise from fall until after the lambing season is over.

Under the head of neurasthemia, Dr. Law has described a condition in pregnant ewes similar to many of the Clinton county cases. A proper diet and enforced exercise, if necessary, are recommended by Dr. Law. Dr. Gohn adopts the same plan with success.

On 4-17-11, I visited the farm of Mr. Rodswell, about 9 miles from St. Johns with Dr. Gohn. We found, in a flock of about 20 or more, three ewes affected and showing symptoms much as has been described. Each showed considerable mucous nasal discharge. None of the sheep could stand. Only four lambs had been dropped thus far. We killed the three affected ewes, all in good flesh.

No. 1 had single fetus nearly full term. Organs nearly all normal. Few Oesoph. columbianum, very few Haemonchus contortus. Rumen, full and contents quite dry and firm. Reticulum, omasum and abomasum practically empty, as was small intestine. Liver showed yellowish tinge and bile ducts and bladder fill of normal bile. Large intestine contained dry, firm feces. Gastro-intestinal mucosa, pale generally. Brain showed very slight congestion of meninges, otherwise firm. One large Oestrus ovis larva found in nasal passages. All nasal mucosa, intensely congested.

No. 2: Not pregnant. Organs nearly all normal, except that the reticulum and abomasum were nearly empty, and the omasum and small intestine were practically empty. Few Oesophagostoma columbianum and very few Haemonchus contortus. Gastro-intestinal mucosa very pale. Liver, yellowish, and gall ducts and bladder filled with bile. Brain as in No. 1. Nasal mucosa intensely congested. In left frontal sinus considerable mass of yellow pus and necrotic tissue or debris. No oestrus larvae.

No. 3: Two fetuses nearly full term. Organs nearly all normal. Few Oesoph. columbianum, and quite numerous young Haemonchus contortus. Rumen contents, normal. Reticulum and abomasum contained only small amount of food. Omasum and small intestine, practically empty. Gastro-intestinal mucosa, pale. Contents of large intestine, dark and very fine. Nasal mucosa, congested. Right frontal sinus contained thickened inflammatory mucosa. One small Oestrus larva found. Brain as in Nos. 1 and 2."—[Ward Giltner.]

Worms in Pigs at Hastings, Mich.—"As a result of considerable correspondence, I visited the farm of M——— — Bros., near Hastings in order to determine the cause of unthriftiness of their pigs. It was known that hog cholera visited this region about seven years ago, and the correspondence suggested chronic cholera. However, they had

demonstrated by their own examination the presence of numerous ascarides in the small intestine and even in the bile ducts and they had carried out a course of turpentine treatment for worms.

Upon my visit, I found the pigs, mostly Chester Whites, in a small enclosure with access to a large clover pasture on the border of a marsh. The pigs were fed ground oats and rye in a slop with only a little milk. Charcoal was constantly before them. They were in rather poor condition and not well developed for their age. Several of the sows were lame in the hind parts, but when made to run the lameness disappeared temporarily at least. The cause of this lameness was not determined. Many of the pigs coughed.

The poorest pig in the lot was killed and carefully examined. Only one ascaris could be found in the small intestine. The lungs showed considerable extension of broncho-pneumonia, probably of verminous origin, but a careful search revealed only one specimen of Str. paradoxus. It seems probable that the treatment had caused the emigration of a considerable number of parasites."—[Ward Giltner.]

COMMERCIAL BACTERIOLOGY.

Miss Louise Rademacher has had charge of the cultures which have been distributed over the state for various purposes. She prepares these cultures, fills orders, and formulates the results. A summary of the cultures distributed is furnished in the following statement by Miss Rademacher:

"No. cultures alfalfa, sent out	1,823
No. cultures red clover, sent out	91
No. cultures alsike clover, sent out	5
No. cultures white clover, sent out	3
No. cultures soy beans, sent out	44
No. cultures white beans, sent out	61
No. cultures peas, sent out	24
No. cultures cowpeas, sent out	41
No. cultures vetch, sent out	30
No. cultures sweet peas, sent out	2
Total	2,124
No. cultures for which collections are outstanding	41
No. cultures sent for special tests (gratis)	36
Alcohol-acetic cultures sent out	31
Lactic cultures sent out	22"

Miss Rademacher also contributes the following summary for the manufacture and distribution of hog cholera serum:

FINANCIAL REPORT ON HOG CHOLERA SERUM MANUFACTURE.

July 1st, 1910-July 1st, 1911.

Feed, concentrated	$733 14
Hay, straw and roughage	51 10
Swine	1,510 25
Apparatus	400 33
Travel	20 02
Labor	2,500 00
	$5,214 84

Value of Receipts and Products on Hand.

Actual receipts for serum and virus	$5,473 68
Actual receipts for pigs	783 42
Value of tested serum on hand (at 2c)	1,246 02
Value of untested serum on hand (at 1c)	1,334 30
Value of unmixed serum on hand (at 1c)	771 42
Value of hogs on hand not in work (market price)	233 60
Value of hogs in work (estimated)	710 00
	$10,552 44
Deducting products on hand July 1st, 1910	2,490 88
Actual value of products for year	$8,041 56

SERUM.

Total No. cc. on hand good, July 1st, 1910	43,348 cc.
Total No. cc. on hand untested, July 1st, 1910	13,536 cc.
Total No. cc. on hand poor, July 1st, 1910	23,910 cc.
Total No. cc. drawn and mixed, July 1st, 1910-July 1st, 1911	268,001 cc.
Total No. cc. drawn and not mixed, July 1st, 1910-July 1st, 1911	77,142 cc.
Total No. cc. drawn for experiment	9,920 cc.
Total	435,857 cc.

Total No. cc. sold, July 1, 1910-July 1, 1911	135,286 cc.
Total No. cc. used for testing and experiment	11,981 cc.
Total No. cc. mixed serum on hand, tested	62,301 cc.
Total No. cc. mixed serum on hand, not tested	133,430 cc.
Total No. cc. not mixed serum on hand	77,142 cc.
Total No. cc. poor serum from last year, destroyed	6,712 cc.
Total No. cc. poor serum on hand	4,481 cc.
Total No. cc. breakage and error	4,520 cc.
Total	435,857 cc.

No. cc. for which collections are outstanding	0 cc.

The serum continues to give good results, in fact, I am disposed to think that our ability to employ it effectively is increasing with our experience in the details of manufacture and application.

It also falls to Miss Rademacher's lot to keep record of the number of tuberculin tests made under the direction of this department. She reports the number as follows:

No. cattle tested for tuberculosis	510
No. cattle condemned	8

The work of this division of the Experiment Station has gone forward during the past year very smoothly and satisfactorily. The spirit manifested in the conduct of all of this work reported has been admirable. Each and every member of the staff has been faithful and persistent in carrying forward his share of the burden.

Very respectfuly submitted,
CHARLES E. MARSHALL,
Bacteriologist.

East Lansing, Mich., June 30, 1911.

REPORT OF THE CHEMIST.

Director Shaw:

I herewith submit the following report of the work of the Chemical Division for the year ending June 30th, 1911.

The work of the division may be divided into three general classes, viz.: investigational, cooperative, including analyses of materials sent in by residents of the state, and the fertilizer control.

The only new line of investigation undertaken during the year was a study of the manufacture and storage of lime-sulfur spray solution. Mr. Jas. E. Harris, who was temporarily engaged during the summer of 1910 to work on this problem, originated new methods of analysis and also brought out some new points in connection with its manufacture and storage.

The lines of research under the Adams fund, "A study of the organic nitrogenous compounds in soils and their variability" and "A study of the chemical factors rendering soluble the insoluble phosphates of the soil," are being continued and the laboratory investigations are now being supplemented by pot experiments.

The cooperative work with the Horticultural Department reported last year is being continued and the experiments at Lawton, on the influence of cover crops and commercial fertilizers upon the yield of grapes, is beginning to create a considerable amount of interest.

One hundred and twenty samples of a miscellaneous nature, sent in by residents of the state, have been analyzed.

The fertilizer control occupies the time of two chemists about four months each year. The number of different brands of fertilizer sold in the state has not increased much during the past year though the actual

consumption of commercial fertilizers is still on the increase and will keep on increasing as the farmers of the state gain a better and clearer understanding of how and when to use them.

The following bulletins have been published during the year:

No. 263—"Fertilizer Analyses"—Andrew J. Patten, O. B. Winter and C. G. Clippert.

Technical Bulletin, No. 6—"Lime-Sulfur Spray"—Jas. E. Harris.

Technical Bulletin, No. 7—"Organic Nitrogenous Compounds in Peat Soils" II.—Chas. S. Robinson.

Circular No. 10—"Manufacture and Storage of Lime-Sulfur Spray" —Andrew J. Patten.

I regret exceedingly to record the resignation of Mr. O. B. Winter, who has accepted a more remunerative position with the New York State Agricultural Experiment Station, Geneva, N. Y. Mr. Winter has been connected with the division since February, 1910, and his zealous performance of the duties assigned to him have made him a very valuable man and his going will be a distinct loss to the institution.

Mr. Clarence Clippert severs his connection with the division with the close of the fiscal year and Arao Itano, a graduate of the college, has been engaged for one year.

In conclusion I wish to express my appreciation to my associates for their untiring interest in the welfare of the division and for the pleasant relations that have prevailed.

ANDREW J. PATTEN,
Chemist.

East Lansing, Mich., June 30, 1911.

NOTE.—The following papers upon "Neutral Ammonium Citrate Solutions" and the use of Busch's "Nitron" for the Determination of Nitrate Nitrogen in Soils and Fertilizers are here published as of interest in connection with the report of the chemist. (Editor.)

NEUTRAL AMMONIUM CITRATE SOLUTIONS.[1]

BY A. J. PATTEN AND C. S. ROBINSON.

Since the proposal of the neutral ammonium citrate method for the determination of available phosphoric acid much trouble has been experienced in preparing a strictly neutral solution of the reagent. The weakness of both the acid and the base renders the end point quite indistinct with ordinary indicators and much time and patience are required on the part of the operator to obtain the desired results. Several complicated modifications of the simple titration method have been proposed but each has objections which prohibit its common acceptation by practical chemists. The importance which the method has assumed

[1]Owing to trouble with apparatus and the interference of other work progress on these experiments was retarded and before their completion an excellent article by Hall and Bell appeared (Journ. Amer. Chem. Soc. 33, 711,) in which it was shown to be possible to use the method outlined. A second article by Hall has since been published (Jour. Ind. and Eng. Chem. 3, 559,) pointing out the practicability of the method for common use. The results given add but little to the material in the above articles and their publication was withheld for some time. It has since been deemed wise to publish them however as corroborating the work of the above authors. They also show through what a wide range the so-called "neutral" ammonium citrate solutions may vary as prepared by the official method.

in agricultural work demands, however, that some convenient means be devised for preparing the necessary reagent.

As is well known, the variation in electrical conductivity offers a means of titrating some solutions with which ordinary indicators fail and it occurred to one of us, that, possibly this might offer a way of overcoming the difficulty in making a neutral solution of ammonium citrate. The method depends upon the velocities of the hydrogen and hydroxyl ions. If alkali is added to an acid solution, i. e., a solution containing free hydrogen ions, the conductivity decreases as the amount of alkali is increased. The reason for this is, that the rapidly moving hydrogen ion of the acid is removed by union with the hydroxyl ion of the base and the current-carrying power of the solution is thrown more and more upon the slower moving anions and cations of the acid and alkali radicles respectively. After passing the neutral point however, the conductivity increases owing to the addition of an excess of the rapidly moving hydroxyl ions. Hence, by plotting the conductivity (or resistance or bridge readings) against the amount of alkali and getting several readings on each side of the neutral point a curve can be plotted which will show a minimum or maximum at the point of neutrality of the solution. From this curve the exact amount of alkali required to neutralize a given quantity of the solution can be predicted. We found that the method worked very well and no trouble was experienced in determining quite accurately the amount of alkali required to neutralize the acid present in the solution used. The method is easily carried out and requires but little more time than the ordinary method of neutralizing with coralline as an indicator.

The method of procedure was as follows: A solution of citric acid was almost neutralized with ammonia, care being taken to keep the density below 1.09. Small samples of this solution were then titrated with a dilute solution of ammonia (about 3%) to determine the approximate amount required to neutralize the remaining acid. Definite quantities of the citrate solution were then removed with a pipette and transferred to clean dry flasks. To these portions of the original solution, varying quantities of the dilute ammonia solution were added in such a way that several contained more and several less than the approximate amount required for exact neutralization, as determined by the titration with coralline. These solutions were then placed in a thermostat the temperature of which was held constant and allowed to come to the temperature of the bath, after which their resistances were measured by the wheatstone bridge method. Plotting the cubic centimeters of ammonia added against the bridge readings, gave a curve from which could be read the amount of ammonia required to exactly neutralize the acid remaining in a given quantity of the citrate solution.

The following tables give the results of two such titrations, 100 c. c. of acid solution being used for each determination. Solution 1 was almost saturated. Solution 2 was diluted so that the addition of the required amount of ammonia brought the density up, almost, to 1.09.

TABLE I.—*Solution 1. Fig. 1.*

c. c. NH_4OH.	Bridge reading.	c. c. NH_4OH.	Bridge reading.
30	582.25	90	610.50
40	594.75	100	608.50
50	603.50	110	606.00
65	609.50		
80	611.00	Neutral.	
		Calc....... 76	611.25
		Observed..................	611.25

Solution 2. Fig. 2.

c. c. NH_4OH.	Bridge reading.	c. c NH_4OH.	Bridge reading.
10	597.25	40	596.50
20	598.25	50	589.50
25.2	598.50	60	582.50
30	598.75		
35	598.25	Neutral.	
		Calc....... 31.50	598.80
		Observed..................	598.75

The results show that 760 c. c. and 315 c. c. respectively, of the dilute ammonia solution were required to neutralize the acid in one liter each, of the acid citrate solutions. Portions of each of the citrate solutions were then measured out, the caluclated quantity of ammonia solution added and the solution diluted to a density of 1.09.

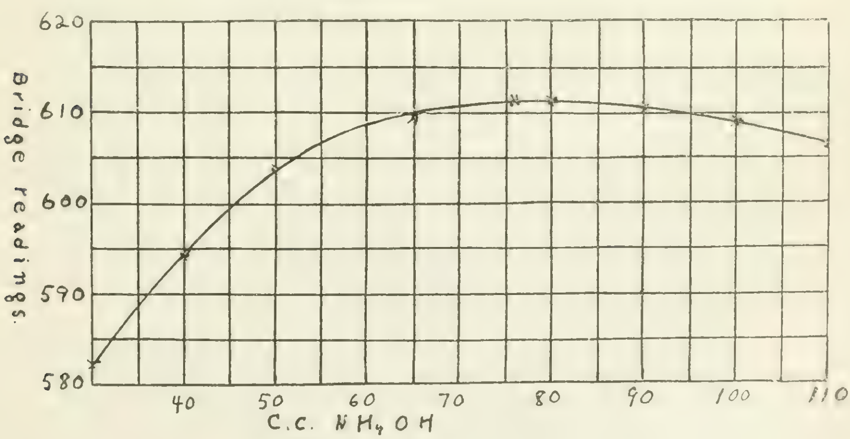

Fig. 1.

In order to determine the personal factor in making up the solutions in the old way, two samples of solution 2 were neutralized according to the official method by each of three laboratory assistants working separately. 100 c. c. portions were taken and the dilute ammonia solution run in from a burette encased in a sheet of opaque paper to prevent the reading being taken till after the supposed neutral point had been reached. In this way each operation was made absolutely independent of the others. The conductivities of the solutions were then taken. The readings were found to fall on the curve obtained by the titration at the points to be expected from the quantities of alkali added. The results are reported in Table 2.

TABLE II.

Number.	c. c. NH_4OH added.	Bridge Reading.	Number.	c. c. NH_4OH added.	Bridge Reading.
PI	36.10	598.25	MI	39.15	597.25
PII	35.88	598.25	MII	37.75	597.50
RI	32.78	598.75			
RII	33.70	598.25			

From an inspection of their positions on the curve the alkalinity or acidity of the various solutions could be determined. As can be seen from the accompanying figure (Fig. 2, points indicated by °) the amounts of alkali vary considerably, 63.7 c. c. per liter between the extremes, and in no case was an exactly neutral solution obtained.

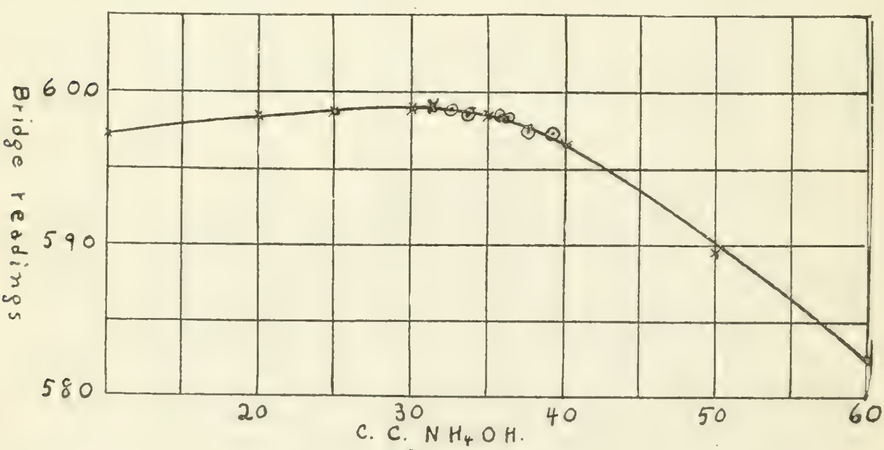

Fig. 2.

These examples fairly illustrate the difficulty of making up a suitable reagent by the official method. It is quite possible that in many cases the character of the "neutral" ammonium citrate solution varies more than in the cases cited and that considerable error may be introduced into determinations in this way.

To ascertain whether or not these differences in the citrate solution would produce marked differences in the results of analyses made with them, several actual determinations were made. The solutions used were conductivity solution No. 2 (C_2) R. II, PI and MI. A sample of commercial fertilizer was used which had been analyzed during the fertilizer campaign of 1911, and the result recorded at that time for insoluble phosphoric acid, was 2.48%. Unfortunately the conductivity of the solution was not obtained.

The four solutions were carefully diluted to a specific gravity of 1.09. Two samples were weighed out for each solution and the official method for insoluble phosphoric acid was followed very closely. The results are given in Table 3.

TABLE III.

Solution C_2.	Solution R_{11}.	Solution P_1.	Solution M_1.
gm. $Mg_2P_2O_7$.	gm. $Mg_2P_2O_7$.	gm. $Mg_2P_2O_7$.	gm. $Mg_2P_2O_7$.
.0235	.0245	.0246	.0266
.0237	.0230	.0241	.0275
.0239	.0246	.0245	
.0237	.0249	.0241	
.0230	.0236	.0239	
.0239		.0238	
Average... .0236	.0241	.0242	.0271
3.01% P_2O_5	3.07% P_2O_5	3.09% P_2O_5	3.45% P_2O_5.

The duplicate results agree very closely in every case with the exception of solution R_{11}. Here we find one result (.0230) as low as the lowest result obtained with the conductivity solution and one result (.0249) higher than any obtained with solution P_1. When, however, we consider the average of the results, we find the result for solution R_{11} falls between those obtained with the C_2 and P_1 solutions.

The results obtained with the three solutions C_2, R_{11} and P_1) are very close and for fertilizer work, at least, would be considered identical in efficiency since variations in the manipulation of the method might cause greater differences than are here reported—However, the fact cannot be denied that solutions R_{11} and P_1 are not strictly neutral and that they give slightly higher results for insoluble phosphoric acid. And furthermore, the solution M_1 adds emphasis to the fact that the present official method cannot be relied upon to give a strictly neutral solution nor even solutions of the same degree of neutrality in the hands of all chemists because it is very difficult to detect just when the change of color takes place.

The conductivity method does give a strictly neutral solution and the authors believe it should be adopted as one of the official methods for determining the neutral point of ammonium citrate solutions.

THE USE OF BUSCH'S "NITRON" FOR THE DETERMINATION OF NITRATE NITROGEN IN SOILS AND FERTILIZERS.

BY C. S. ROBINSON AND O. B. WINTER.

The object of the work reported in this article is the comparison of the official zinc-iron reduction method for the estimation of nitrate nitrogen with the so-called "Nitron" Method of Busch, as applied to soils and fertilizers. In the course of the work now being done in this laboratory, on the nitrogenous compounds of humus, it became necessary to run a considerable number of nitrate determinations on soils rather rich in organic matter. It was thought that under the influence of the strong reducing agents used in the official method some of the organic nitrogenous compounds might be broken down with the formation of ammonia, thus, causing high results. We hoped to adopt some modification of the "Nitron" method to the work and eliminate this source of error. The results were, however, not at all satisfactory. In a few cases on ordinary soils good results were obtained but if any considerable amount of organic matter was present, the precipitate, if at all crystallin was dark colored, and in many cases only brown flocculent material was thrown down.

This was not true in the case of commercial fertilizers as was anticipated from the fact that several articles,[1] have recently appeared, reporting good success with the use of "Nitron" for the determination of nitric nitrogen in commercial nitrates. Occassionally brands of commercial fertilizers are encountered with which it is difficult to get consistent results using the official method for nitrates and it is highly desirable that some new method, applicable to such cases be developed. A number of comparative analyses were made by the two methods on brands giving good results with the official method to see if equally good results could not be obtained with the "Nitron" method. The results were very satisfactory and it seems probable that the "Nitron" method could be used to advantage in the analysis of such material.

ACCURACY OF THE METHOD.

Busch claims that "Nitron" or 1.4-diphenyl-3.5 endanilodihydrotryazol will precipitate nitric acid from solutions of one in sixty thousand at ordinary temperatures and one in eighty thousand at zero degrees. This

[1]L. Radlberger, Osterr. Ungar. Ztschor. Zuckerindus. u. Landw. 39, 433 (Abs. in E. S. R. 24, 120).
A. M. Wasllieff, Zhur. Russ. Fiz. Khim. Obsch. Chast Khim 42, 567, (Abs. in E. S. R. 24, 609).

would be equivalent to 0.00004-0.00003 parts of nitrogen per hundred which is quite as accurate as the ordinary distillation methods. The fact that the nitrate nitrogen forms only 3.73% of the weight of the precipitate greatly increases the accuracy of the method over ordinary analytical methods.

NITRATES IN SOIL.

The following method of procedure was used in the analysis of soils. 100g. (or a larger quantity if necessary) were weighed into a beaker and thoroughly stirred with hot distilled water to form a thin paste. After standing some time the liquid was drawn off with suction and the residue washed on the filter with hot water till the filtrate amounted to 200-300 c. c. The combined filtrate and washings were then concentrated to about 100 c. c., filtered through a folded filter, to remove sediment which may have accumulated during concentration, and the filtrate further concentrated to 50-75 c. c. To this liquid while still hot a few drops of (I-I) H_2SO_4 were added and then 5-10 c. c. of a solution of "Nitron" in 5% acetic acid. During the addition of precipitating reagent the solution was vigorously stirred and the sides of the beaker scratched to insure precipitation. The beaker was then set in ice water or in the cold chamber of the refrigerator for several hours or over night. At the end of this time the precipitate was transferred to a weighed gooch crucible[1] by means of the mother liquor and washed with a few c. c. of ice water applied in a fine jet from a wash bottle. It was dried to constant weight at 110°.

For the distillation method the soil was extracted as above and the ammonia removed from the extract by distillation with MgO after which the residue was treated as directed on p. 10 method "h" of the official methods.

EXPERIMENTAL.

A mixture of 200g. of pure quartz sand and 350 mg. of pure KNO_3 was prepared and extracted as above. The extract was concentrated and made up to 200 c. c. of which aliquots of 25 c. c. were taken for analysis.

"NITRON" METHOD.

25 c. c. samples gave 0.1612 and 0.1607 g. "Nitron nitrate"=6.01 and 5.99 mg. N respectively.

DISTILLATION METHOD.

25 c. c. samples gave NH_3 equivalent to 4.05 and 4.00 c. c. N/10 H_2SO_4=5.67 and 5.60 mg. N respectively.

Theory = 6.06 mg. N.

The following are some of the results obtained with samples of soil collected at random from various fields on the college farm.

The results are not at all concordant.

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[1]After weighing, the precipitate can be burned off and the same crucible used repeatedly.

Sample number.	Mg. N. Per 100 g of Soil.	
	Distill.	"Nitron".
1	6.65	7.10
2	0.88	0.40
3	3.85	4.58
4	0.86	0.38
5	4.90	2.17
6	5.76	5.96

From the appearance of the precipitates and from the fact that fairly good agreement was obtained with pure quartz sand it seems probable that the error is due to the humus in the soil.

NITRATES IN COMMERCIAL FERTILIZERS.

With fertilizers much better results were obtained. The following table gives some of the results with various samples, some of which were quite pure sodium nitrate while others were mixed fertilizers. Preliminary tests were made with diphenylamine. Five to ten grams of the sample, according to the apparent amount of nitrate present, were weighed into 500 c. c. flasks, dissolved, and made up to volume. Aliquots were taken and analyzed as described above except that concentration was usually unnecessary and in some cases the sample was diluted to 75-100 c. c.

Sample number.	Distill. Method.	"Nitron." Method.
2839	15.84 15.70	15.70 15.67
2932	15.14 15.14	15.18 15.08
2727	15.56 15.42	15.66 ....
2810	15.56 15.56	15.39 15.40
2873	15.56 15.70	15.52 15.59
2830	15.70 15.70	15.62 15.54
2798	1.23 1.26	1.21 1.21
2751	1.18 1.16	1.10 1.10
2711	0.62 0.62	0.60 0.60
2717	0.17	0.12 0.24
2890	1.43 1.40	1.37 1.38

The results check up well as a whole, the duplicates in the "Nitron" method agreeing slightly better than in the distillation method. In nearly every case the "Nitron" results are a little lower than the others. This is less than 0.2% in every case. It is probably due to the solution of some of the "Nitron" precipitate rather than high results in the distillation method, as the results in that column are corrected for a blank run on the materials used in the analysis.

The "Nitron" method presents some advantages over the older method in that it requires less actual time on the part of the operator than does the distillation method and the number of samples that can be run simultaneously by one man is limited by his own ability and not by the capacity of any one piece of apparatus as in distillation method.

In summing up the work it might be said that the "Nitron" method seems to be generally inapplicable to the determination of nitrate nitrogen in soils but can be used to advantage in the determination of this form of nitrogen in fertilizers. The reason for its failure in the case of soils is the presence of organic matter which either contaminates the precipitate or holds it up.

REPORT OF THE HORTICULTURIST.

Director R. S. Shaw:

Sir:—I herewith submit a report of the Horticultural Division of the Experiment Station.

The cover crop and fertilizer tests have been continued in three vineyards near Lawton. In this large grape growing section, cover crops are not used to any extent nor is much fertilizer of any kind used. It is our belief that a continuation of this way of handling the land will lead to a marked reduction of the yield of grapes. This has occurred in some of the grape growing regions of New York. The use of cover crops must be adopted; chemical fertilizers alone will not maintain fertility and it would be impossible to secure enough manure for this purpose.

We want to determine the most suitable plant or plants for a cover crop under the local conditions. The effect of using four hundred or five hundred pounds per acre of a "home mixed" fertilizer in connection with and without the cover crop, is also being tested.

Among the cover crops under trial are buckwheat, velvet bean, spring vetch, cowpeas, winter vetch, oats and rye. After two years of some of these crops with the resulting humus, the clovers will be tried.

The fertilizer tested was of the following formulas:

300 pounds acid phosphate.
100 pounds sulphate of potash.

400 pounds per acre.

100 pounds dried blood.
300 pounds acid phosphate.
100 pounds sulphate of potash.

500 pounds per acre.

400 pounds tankage.
100 pounds sulphate of potash.

500 pounds per acre.

So far the observations upon the cover crops indicate that the winter vetch sown in August, at the rate of thirty pounds per acre, is the most satisfactory.

The influence of the cover crop and fertilizer upon the yield cannot be obtained until this fall (1911) since the tests were not started until August, 1909, and in 1910 the grape crop was only about five per cent of a normal crop owing to the late spring frosts. These tests are being followed with much interest by the grape growers in the vicinity of Lawton.

The effects of cover crops in orchards are in progress at South Haven, Casnovia, Scottville, Ludington and Bellaire. The plot in each place comprises six acres of as uniform soil as it is possible to secure. Plants that are being tested include the clovers, vetches and various mixtures of plants that grow rapidly in the fall and others that grow rapidly in the spring. Other conditions being satisfactory, an effort is made to locate these tests in an orchard that is conspicuous and of easy access to all fruit growers in the vicinity. Much good has already resulted from the observation of neighbors.

The most promising plant so far tested is the winter vetch, twenty-five to thirty pounds of seed per acre sown in July or August.

Tests have been continued to determine the advantages of spraying potatoes to protect them from late blight and rot (Phytopthora infestens). Last fall (1910) upon the college grounds, one acre of potatoes were grown under uniform conditions of soil, fertilizer and seed. Every other of four rows were sprayed with Bordeaux mixture (six pounds copper sulphate, four pounds of lime to fifty gallons of water) and when needed, Paris Green (½ pound to fifty gallons of Bordeaux). Sprayings were made on July 8th, 22nd; August 5th, 19th and September 2nd. Paris Green was needed in the first two sprayings. The alternate four rows were protected from bugs by spraying with Paris Green on July 8th and 22nd. At no time could blight (Phytopthora infestens) be found on the plants. At digging time, the yield of each row were sorted into marketable potatoes and "culls," the latter being those smaller than a hen's egg. The gain for the five sprayings was 43 bushels 28 pounds of marketable tubers.

The cost of spraying and of the material is from eighty cents to one dollar per acre, for each application. This increase in the yield, in the absence of the blight, is due to the stimulation of growth that

results from the spraying with Bordeaux. This effect has been noticed for many years in other places.

Since potatoes usually are sprayed for bugs, it would be well to use Bordeaux mixture with the poison and to make one or two sprayings.

Fertilizer tests with potatoes were made upon a plot of land that was very uniform and had been handled in a uniform way for a number of years. The plots were one-quarter of an acre each.

In 1907, the field grew a heavy crop of clover which was turned under; in 1908 it produced tomatoes and in 1909 corn. The planting, cultivating and spraying was uniform for all plots.

The fertilizers used consisted of two "home mixed" lots which will be designated "A" and "B" and a complete commercial brand which will be designated "C." The "home mixed" lots were made up to give four per cent nitrogen, (in "A" 1½ per cent from the nitrate of soda and 2½ per cent from the dried blood), seven per cent phosphoric acid and ten per cent potash. The complete commercial brand contained 1.65 per cent nitrogen, 8 per cent phosphoric acid and 10 per cent potash.

"A" was made up as follows:

194	pounds nitrate of soda, at $54.30 per ton..............	$5.27
357	pounds dried blood, at $52.20 per ton	9.32
1,000	pounds acid phosphate, at $12.00 per ton	6.00
400	pounds sulphate of potash, at $49.00 per ton	9.80
49	pounds filler	
		$30.39

"B" was made up as follows:

570	pounds dried blood, at $52.00 per ton	$14.82
1,000	pounds acid phosphate, at 12.00 per ton...............	6.00
400	pounds sulphate of potash, at 49.00 per ton	9.80
30	pounds filler	
		$30.62

"C" was a "complete" potato fertilizer costing $31.50 per ton. At digging time the potatoes were sorted into marketable tubers and "culls." The yields given are for the marketable tubers only.

Plot 1—500 pounds "A" per acre cost $7.60, yield 205 bu. 32 pounds.

Plot 2—1,000 pounds "A" per acre, cost $15.20, yield 212 bu. 20 pounds.

Plot 3—Check, not fertilized, yield 152 bu.

Plot 4—500 pounds of "B" per acre, cost $7.65, yield 155 bu. 44 pounds.

Plot 5—1,000 pounds of "B" per acre, cost $15.30, yield 200 bu. 48 pounds.

Plot 6—500 pounds "C" per acre, cost $7.71½, yield 151 bu. 48 pounds.

Plot 7—1,000 pounds "C" per acre, cost $15.75, yield 173 bu.

This test indicated that the "home mixed" fertilizer designated as "A," used at the rate of 500 pounds per acre was the most economical and its use paid in comparison with land not fertilized.

Spraying tests on orchard fruits are being continued. The object is to determine the comparative value of the self-boiled lime-sulphur mixture, the dilute boiled lime-sulphur and the Bordeaux mixture on apple, cherry, plum and peach. These tests are being made at South Haven and at Hart.

The strawberry crosses made several seasons ago, were again fruited and careful notes secured. Several kinds appear to be of value but further testing is, of course, necessary.

Several experiments are in progress but from the nature of the work, it is not possible to make even a preliminary report as to results.

Respectfully submitted,
H. J. EUSTACE,
Horticulturist.

East Lansing, Mich., June 30, 1911.

REPORT OF THE SOUTH HAVEN SUB-STATION.

To H. J. Eustace, Horticulturist, East Lansing, Michigan:

Sir:—I herewith make a brief report of the work done at the South Haven sub-station for the year ending June 30, 1911.

Variety tests of strawberries have been discontinued because the soil on the station property is not at all desirable for strawberry culture. This variety testing required considerable time which has been used in making spraying tests on fruit trees, and study and observation of lime and sulphur for spraying purposes.

Extensive tests of the comparative value of Bordeaux mixture, self-boiled lime and sulphur and the commercial diluted lime and sulphur on apple, peach, pear, plum and cherry trees were planned in the spring of 1910, but a failure of the fruit crop resulted in abandoning them. Similar tests were started this spring (1911). Plans are made for observation of the codling moth. Fruit growers will be notified of the best time to spray for both broods. It is believed that the work will be of great benefit to the fruit growers of this section and greatly appreciated by them.

There is a great need for better opportunities to do field experimental work. The station orchards are not at all suited for good tests as there are so many varieties and only a few trees of each. These varieties have been reported year after year and it does not seem wise to continue it. If the money spent on the care of these varieties could be spent for field experiments, it is believed the results would be of much more economic value.

A large amount of the time of the superintendent has to be given to

the general care of the orchards and disposing of the fruit. Heavy demands of time are also made by fruit growers of the vicinity for advice on spraying and other work of almost every kind. This time is always cheerfully given for this work. Among the recent troubles that have been important enough to demand attention, are the green fruit worm, fruit tree bark beetle, New York weevil, tarnished plant bug, cottony maple scale, winter injury of the peach and the Chermes scale on the white pine.

Among the new or little known varieties of apples, the following produced good crops:

Arctic.	Fameuse Sucre
Akin.	Fulton.
Arkansas Beauty.	Hamilton Black.
Beauty of Bath.	Horse.
Black Annette.	Springdale.
Dudley.	Spencer.
Douglas Seedling.	Winter Banana.

These varieties have been described in previous station reports.

Special mention should be made of the Winter Banana. We have grown a number of crops of this variety. The crop last fall was especially fine, possibly due to the sprayings with lime and sulphur instead of Bordeaux mixture. The fruit grown here compared very favorably with specimens from western states on exhibition at the land show in Chicago last November. Western growers complain that it is difficult to pick without bruising. At the time for picking here, the fruit is firm and does not bruise easily. Our experience leads us to believe it to be a variety that should be growing in Michigan.

The Fameuse Sucre or Sweet Snow is the handsomest and best quality apple we have on trial. It is as large as a good sized Snow apple, the flavor is better than the Snow, the color is almost entirely a dark glossy red which is brought into attractive contrast with its white, crisp, juicy flesh. It does not scab as badly as the Snow, and ripens at the same time. If placed in cold storage immediately after picking, it would be prime for the Christmas trade.

To make an extensive test of the lime and sulphur as a summer spray, it was used entirely in the general spraying instead of the usual Bordeaux mixture. A concentrated commercial article was used at the rate of one gallon to forty-nine gallons of water to which was added two pounds of arsenate of lead. The result of using this on some four hundred varieties of fruits, both tree and small except strawberries, was satisfactory. Scab on the Flemish Beauty pear and rot on the Victoria plum, which were never well prevented by Bordeaux mixture, were almost entirely controlled this season by lime and sulphur.

The black rot of the grapes was not well controlled by spraying with lime and sulphur nor was the foilage healthy.

The color of fruit sprayed with lime-sulphur is better than that sprayed with Bordeaux. Probably because the lime and sulphur does not

cover the fruit as thickly as Bordeaux mixture does. It can be used nearer to the picking time than can Bordeaux and not show staining. This advantage makes it valuable when a late spraying of plums for rot is desirable. Used at the rate of one gallon to seventy-four of water was satisfactory in preventing rot on plums.

Injury to pear foilage is sometimes reported where lime and sulphur is used at the rate of 1 to 33 or 40. In our own spraying there was a slight burning from the use of a home-made concentrated lime and sulphur testing 30 degrees Beaume used 1 to 33. Upon investigation, it was found that the cap in the spray nozzle had worn large from previous sprayings and this threw a spray that was too heavy. Other cases of reported burning, when examined into invariably result in showing that the spray rod is held too long in one place or in turning at the end of a row the tree is sprayed too much.

Drenching the leaves with lime and sulphur when used as a fungicide at the strength of 1 to 33 or 40 is not advisable. However, probably 1 to 50 should be used on pears.

Peaches and Japanese plums which are very seriously injured by spraying with Bordeaux mixture, even when used as weak as 1½ pounds of copper sulphate and 3 pounds of lime to 50 gallons of water were sprayed with lime and sulphur testing 33 degrees Beaume at the strength of 1 gallon to 49 gallons of water without injury in 1910 and 1911. Reports from other states indicate injury from the strength of 1 to 99 gallons of water. New Jersey experiment station (Bulletin 236) reports injury from a strength of 1 to 100. One local fruit grower who was misinformed, sprayed peach trees about three weeks after the blossoms dropped with lime and sulphur 1 to 40 strength and did not have the slightest injury.

Since there is such wide differences in the burning of peach foliage, sprayed with lime and sulphur of the same strength, it is apparent that there is something aside from the proportions of materials used, to cause the differences. These may be weather conditions, climate or the method of application.

During the past three seasons, we have been using the lime and sulphur (33 degrees Beaume) 1 to 10 applied just before the blossoms opened with the idea of making the one spraying take the place of the one usually made earlier for scale and the usual one at that time of Bordeaux mixture for fungus troubles. In 1910 and 1911 all the tree fruits in the station orchard were sprayed this way. Only slight burnings were noticed where the trees were too heavily sprayed. At the time of this spraying, the leaves and buds have a natural protection that seems to prevent burning that would occur later. From our results and those of fruit growers in the vicinity, this system is very promising.

Respectfully submitted,
F. W. WILKEN,
Superintendent.

South Haven, Mich., June 30, 1911.

REPORT OF THE BOTANIST.

Director R. S. Shaw:

Sir: I submit herewith, the following report of the work of the Botanical Division for the year ending June 30, 1911.

The positions provided for by the action of the Station Council a year ago namely Research Assistant in Plant Physiology and Research Assistant in Plant Pathology were not filled until respectively November, 1910 and January, 1911. A large part of the time of the two men for the first two or three months, was devoted to planning for the laboratory and arranging for the purchase of proper apparatus. The quarters occupied by them first, namely the northeast room on the second floor of the old part of the Botanical Building, proving too small, room 16 and the adjoining office in the new part of the building were assigned for the use of the botanical division. These rooms have been fitted with gas and electrical connections and the apparatus has been set up in them and much of it is now in use although some is of so recent arrival that it has not yet been set up. Owing to the delay in the arrival of apparatus and interference with work due to the removal of the office, there are no results of importance to report from the work of either of the men. Prof. Coons has made one or two trips to different parts of the state in connection with the investigations of canker disease on apple and peach and has been busily occupied with answering correspondence with regard to plant diseases. Dr. Brown has been planning his work and getting under way certain experiments on some problems of soil physiology of plants.

The examination of seed samples in accordance with the provisions of the pure seed law has been put under my direction and has required a considerable part of my time. The seeds were collected by a special seed inspector and were examined by students who had been trained in the study of weed seeds, Mr. Mancel T. Munn having charge of the work of the students. A report on the results of the tests will be issued this summer.

Respectfully submitted,
ERNST A. BESSEY,
Botanist.

East Lansing, Mich., June 30, 1911.

REPORT OF THE ENTOMOLOGIST.

Director R. S. Shaw:

Dear Sir:—Following is a brief report of the work of the Division of Entomology for the year ending June 30, 1911.

The season, thus far, has been made notable by a very bad invasion of cutworms, and by plant lice in the orchards. Three species attacked the opening buds and threatened grave injury but two of these species migrated to other hosts and parasites seem to have taken care of the third species, (the rosy apple louse). Tussock moths and rose-chafers are more abundant than usual but agriculturists are becoming better acquainted with their control now than in the past. Wire-worms are making some trouble and the cottony maple scale is just now becoming a prominent pest.

The writer has been unable to make much progress in his study of insect diseases owing to press of other duties and also to difficulty with the eyes, due to long continued work of this sort.

Many species of insects have been bred and determined in connection with the complaints which are constantly coming in, complaints about pests and supposedly noxious insects. Correspondence in relation to such cases seems to be greater than ever before and replies to inquiries now demand quite an appreciable effort in giving advice.

During the late winter a revised edition of the Spray and Practice Outline was prepared by Prof. Eustace and the writer, and published as Special Bulletin 54, and some few field experiments in spraying are being carried on jointly by the departments of horticulture and entomology.

Dr. Geo. D. Shafer has just prepared a bulletin on the first part of his problem, "How do Contact Insecticides Kill Insects."

For several years past the writer has been making special efforts to find some effective measures for the control of the tamarack sawfly, (Lygaeonematus erichsomii) an imported insect that has caused the loss of a large part of the larches and tamaracks in the United States and Canada.

Recently, at a great expense and after several trials a parasite has been imported from England by Dr. C. Gordon Hewitt, Dominion Entomologist of Ottawa, Canada, and he, through our National Bureau of Entomology, has generously supplied us with part of his material for trial in Michigan.

In order to successfully introduce parasites of this type, it is necessary to bring them to maturity from the pupal stage in which they pass the winter, at just the right time, so that they may lay their eggs in the young caterpillars of the sawflies in the forest. They must be placed where they can mate and then be liberated, without turning loose any of the parasites of the parasites which would render nugative the entire work if allowed to do so.

In order to insure so far as possible the successful liberation of these beneficial insects, a screened-in cage enclosing two larch trees in the nursery, was built and the parasites which first emerged were turned into this. Later when the northern sawfly started work the parasite material was moved to the Upper Peninsula and specimens liberated there. It is hoped that the parasites may gain a foothold and in time make it possible to once more grow tamaracks in northern Michigan.

Respectfully submitted,
R. H. PETTIT,
Entomologist.

East Lansing, Mich., June 30, 1911.

REPORT OF SOIL PHYSICIST.

Director R. S. Shaw, College:

Dear Sir:—My annual report for the year just closing is not so large as I had hoped a year ago that it might be. Over a year ago I was authorized to procure a research assistant for this department. The agreement was closed by which we were to procure a very excellent man for the place but a variety of circumstances made it impossible for him to take up the work. Later we procured the services of Mr. George J. Bouyoucos. At the time we procured his services, Mr. Bouyoucos was a student at Cornell University working for his doctors degree. He was unable to take up the work with us until his work at the university was completed. He took up his duties on the 20th of June. This delay in procuring a research assistant has interferred very largely with the work of this department as planned a year ago. We are looking forward, however, with much hope to the year that is before us. Some of the research work planned has been done however, and while not a sufficient amount to warrant the publishing of results, they are none the less valuable.

This department has cooperated in the soils survey work in Roscommon county. A number of mechanical analyses have been made of the various types of soil found in the county. The results of these analyses will appear in Mr. Raven's report. The work of analyses has been done quite largely under Mr. Spurway's direction. Mr. Spurway has also given attention to lines of work under the Hatch fund described a year ago.

Respectfully submitted,
JOS. A. JEFFERY,
Soil Physicist.

East Lansing, Mich., June 30, 1911.

REPORT OF FARM CROPS EXPERIMENTS.

Director R. S. Shaw:

I have the honor to submit the following report of the Division of Farm Crops for the year ending June 30th, 1911.

CROP IMPROVEMENT.

The crop improvement work has been carried on along the same lines of previous years. The present season's work promises on the whole a more satisfactory comparison of the different varieties and strains than those of preceding years. It is gratifying to report that this work has now been carried on for several years and sufficient data accumulated to enable a choice of some of the better strains for distribution over the state. A few of these have already been distributed in a small way and seed is available from increase plots on the station grounds for further distribution. The extent of the plant breeding investigations carried on by the experiment station is shown by the following report by Mr. F. A. Spragg, research assistant in plant breeding, who has had immediate charge of this work.

The work of developing new high-producing varieties, that have descended from single seeds and have been increased and tested out in variety series, has been outlined in past years and is being continued. The work with soy beans, cowpeas, timothy, and clover is being continued as reported last year. A large number of select clovers were set out in new nursery this spring.

The plan has been to leave the work of developing new varieties, by artificial cross-breeding, largely in the background until the work of finding and testing out of high-producing lines indicates valuable strains to be used as parents of our new varieties. Some of the strains of oats were started by Prof. J. A. Jeffery in 1900, and are now well studied. The best of these have been crossed this year to see whether it be possible to obtain more valuable sorts. We are also attempting some hybridization between the different species of Trifolium, Medicago and some of the other genera of the legumes. The reason for this is the fact that some of the types of clovers and alfalfas that are not in themselves high producers are very hardy and resistant to disease. It is hoped that a cross between these and high-producing types will enable us to find more desirable varieties.

Wheat.—There are 248 plots of wheat. Of these 75 are larger yield plots; 65 are smaller yield plots; 13 are small increase plots; 35 are head-row plots; 42 are plant-row plots, and 18 are selection plots.

Oats.—There are 323 plots of oats. Of these 3 are large increase; 80 are larger yield plots; 35 are smaller yield plots; 191 are plant-row plots, and 14 selection plots.

Barley.—Eight plant-row plots of winter barleys were started last fall. Three of these strains stood the winter with no winter-killing so far as can be observed. The remaining five lots were more or less

injured. Two or three of these will probably be dropped for this reason. The others will go on to variety series.

In the spring barleys we have 66 plant-row plots, selected last year, mostly from among foreign lots. The remainder of the work is as reported before.

Rye.—We have four strains of winter rye in plant-row plots this year that appear to be much superior to the common run of ryes in the state. They enter the variety series along with the common rye this fall.

Field Beans.—The work with beans has been increased by including a number of new varieties into the variety series.

Alfalfa.—During the winter quite a number of small lots of station grown alfalfa seed were sent out to farmers of the state, who wished a start from Michigan seed-producing strains. These lots of seed came from select mother plants.

A small variety series of alfalfa was started this spring. Some of this work also is being undertaken by farmers over the state. In time the work will furnish Michigan her own alfalfa seed.

SOIL FERTILITY EXPERIMENTS.

The Davenport fertility and rotation experiment was discontinued last year and a summary of same appears later in this report.

The new fertility and rotation experiment in Field 9 has been carried out as previously planned. This experiment includes the study of several three-year rotations, continuous cropping of certain crops and the use of several grades of fertilizers and manures. Each rotation is triplicated so that all of the crops are planted each year. While it is agreed that the fertility questioned is largely a local one, it is hoped that this experiment will at least point the way as to what should be tried in other sections and help to demonstrate certain fundamental principles to students and college visitors.

EXTENSION WORK.

Last season was quite unfavorable for the variety tests of corn planted by the experiment station and two of these were abandoned before maturity of the crop. The other three tests were harvested, one of them making a satisfactory test and the other two only fairly so. This experiment is being continued this season with a smaller number of varieties, including some of the best from last years trials and a few additional ones.

The efforts of the department in extension work have been devoted mainly to the introduction of alfalfa. Some time was devoted to this work during the summer and fall of 1910 and since March 28th, 1911, the farm crops field agent has been continually engaged at it. This work has been facilitated by the organizations of alfalfa clubs of ten or more members, each of whom agrees to grow an acre or more of alfalfa. The college representative holds an evening conference with the members if feasible, then drives to the different farms the next one or two days, assisting the farmer in picking out suitable fields and

giving necessary instruction for planting, etc. Up to the present time 66 clubs have been organized 11 of which are in the Upper Peninsula and 55 in the Lower Peninsula. Of those in the Lower Peninsula, all have been visited except three. Those in the upper Peninsula have been turned over to the superintendent of the branch experiment station, at Chatham. The interest manifested in this work by the farmer has been very gratifying. It also offers one of the best means of meeting the farmer with the least expenditures of time and money.

The seed distribution has grown somewhat from that of previous years. This work will doubtless be facilitated by the Michigan Experiment Association, which was organized January 17th, 1911, and whose objects are stated below: "The objects of this association shall be to promote the agricultural interests of state:

1. By carrying on experiments and investigations beneficial to those interested in progressive agriculture.

2. By the organization of farmers in a united effort toward the study of local agricultural problems.

3. By the distribution of improved seeds and the gathering of data in regard to the adaption of same to conditions in various sections of the state.

4. By the holding of farmers' meetings and exhibitions of farm products and by the desemination of scientific knowledge as applied to Michigan agriculture through such other means as may be most efficient.

Other lines of extension work such as assisting at corn shows, fairs, farmers' institutes, agricultural trains etc., have continued about as last year.

The following paper on "Methods of Keeping Crop Records at the Michigan Experiment Station" was prepared by Mr. F. A. Spragg and read before the American Society of Agromony in November, 1910. It will give a good idea of the methods used in the development of better strains of the various farm crops at the experiment station and should be of special interest to those engaged in plant breeding.

METHOD OF KEEPING CROP RECORDS AT THE MICHIGAN STATION.

In appearing before you on the subject, The Keeping of Crop Records at the Michigan Station, my object is to outline the general plan and give some reasons why our methods came into use. As you are workers in this field, you will recognize that any fit system will be applied to new uses and change somewhat in detail as time goes on. Our system is composite in origin, but the aim is to outline only such methods as have established themselves. In case the steps are not clear, the author would be pleased to answer questions, and would also be pleased to hear why any point may not be workable in another state.

REGISTER, PLANT AND PROGENY NUMBER.

The numbers that are being used in listing the various plots of a season, in showing their relationship, in giving individual numbers to our various selections and in tracing a pedigreed strain throughout its final yield and quality testing, are all members of the same system.

Our register number consists of three parts; viz., the date, plot number, and selected plant number. Before selections are made, the last two figures are zeroes. In this form it stands for the whole plot. For example, 84700 stands for the forty-seventh plot of 1908. 84715 is a single plant. It is the fifteenth selection from the above plot. If the selections are ears of corn to be analyzed and later planted, these numbers may follow the ears through the laboratory back to the field, and the good thing about it is that they indicate the origin at all times.

Each crop has a separate series of register numbers. Some workers are using a separate series for each variety. We have found our accessions to be mixtures, and that several of them may contain the same elementary species or strain. Thus the ordinary varieties overlap, but all of them may be included under the head of the crop. Each crop has a new set of elements and new problems. There is no reason therefore for including more than one crop in a series. However, we must have the name of the crop as well as the number when any question is asked concerning one of our pedigreed strains.

Whenever a select plant becomes the mother of a promising strain, the individual plant number, becomes the strain number. For example, we have a cowpea 60901. (Fig. 1 shows an increase plot of this, summer, 1909.) As can be seen, this strain sprang from the first selected plant of the ninth plot of 1906. Wheat 016600, or the 166th wheat plot of 1910, was a member of a twentieth acre series, shown in Fig. 13, and originated in a single plant (wheat 61202) the second selection from the twelfth plat of 1906. In our wheat register, the two members follow each other on the same line. The one stands for the current year and the other indicates the pedigree.

With perennial plants, the date in the register number refers to the year that the plot was started from seed. Alfalfa 90800 is the eighth row or plot in a series started in 1909.

CENTGENER OR PROGENY.

We make no distinction in meaning between the words centgener and progeny. It may be any number of plants produced as the direct descent of a single plant. These plots are planted in blocks or in rows as the problem at hand seems best to be served. Selection plots in their first year are called beds. This is the starting point from which individual plants are selected to become mothers of centgeners or progenies.

BASIS OF SELECTION.

The individual plant is the basis upon which all the work is done. In the case of small grains, the threshing machine has carried its gifts around until the commercial variety means little. The testing out of these mixtures can give only general ideas. When we have enough seed of lots that have descended from single plants to plant our variety series, we begin to get results. Those showing poor quality or yield are discarded. If we have done nothing more than to pick out the highest producing strain in one of these commercial varieties, the yield has been increased several bushels. Hybridization is being left largely in the background until the work of finding and testing of high producing strains indicates valuable material to work on. We know how a small grain hybrid will break up often for generations, especially if the crossing has been complex. In the case of cross-fertilized plants, we deal with hybrids from the outset.

In working with alfalfa and clover for the past four years, where thousands of individual plants have been studied in the nurseries, the writer has been convinced that the problem of producing pure strains is a difficult one. If we had the original corn from which man has selected the corns of today, or if we had all the varieties of dent, sweet, pop, flint, and pod corns not only mixed together but completely intercrossed, in the same field we would have a corn condition that would approximate the ordinary red clover of today. It is hoped that by passing our strains through a long series of individual plant selections, discarding the undesirable and unproductive of each generation, and planting only the best, we can in time obtain a clover as uniform in character as some of the better varieties of corn today.

NOTE BOOKS—RECORD SHEETS.

We use the standard letter size paper (8½ by 11 inches) in all our note books. The sheets have two holes near one side to fit the Welch covers. This makes them adaptable to all the varying needs of the often strenuous note-taking day. Portions of a number of records can be taken to the field under one cover. Index fobs on extra sheets may

be arranged to enable one to find the subjects easily. Blank sheets can be sandwiched into the records at any point. And, if there is a rush job on, this system allows one register to be divided into two, at any point, allowing two classes of notes to be taken at the same time, by different persons or groups.

The horizontal lines on the two sides of a record sheet are exactly opposite. This causes a line on one page to fit that of the next page, and allow a record to continue there.

Accession Number Book. Figs. 2 and 3.*

When a lot of seed is received, it is given an accession number. Each class of plants receives a separate series of accession numbers. In other words, each crop has a number book. The same blank is used for all of the crops, the name of the crop being filled in at the top. The two sides of the sheet are printed with columns to suit the opposite pages. The headings are: number, variety, source, date received, amount received, date entering nursery, and remarks.

Hybrids produced at the station receive a new number when they enter the nursery. In this case, the variety column shows the numbers of the parents, written as a common fraction. The number of the dam becomes the denominator.

MICHIGAN NUMBER BOOK.

Individual plant number and strain number have already been explained. These follow the seed as long as it remains at the station. We have also used them in sending small quantities of seed to farmers. A pedigreed strain can seldom be called by any existing name, and our strain number is large and apt to be forgotten by farmers. Therefore, as soon as quantities of these new productions are to be distributed, we plan to send them out under a new series of numbers, called Michigan numbers. These will differ from the accession numbers in that the seeds descend from individual plants at the station.

Registers. (Figs. 4, 5, 6, 7 and 8.)*

Each crop has a register suited with columns to its needs. In general, the opposite pages are used for one record. Each line takes care of a plot. The columns on the left hand pages (Figs. 4 and 6) are suited to a description of the mother plant, and those on the right hand pages (Figs. 5 and 7) to the taking of notes on the progeny or increase plot. The first three columns are: register number, plant or strain number, and accession number. Others vary with the crop in question. Where a quantity of blanks are needed, they are printed. Others are copied on the hectograph, or small quantities with carbon sheets. Increase and variety series are entered on the same blanks as are used

*For blank forms see pages 200-206 inclusive.

for the progenies and beds. The plot numbers run serially throughout all there groups of plots for a season.

The register of an annual crop like oats (Figs. 4 and 5) is fully explained by the cuts. In the case of perennial crops like alfalfa the problem is more complex. It will be noticed that Fig. 7 is a narrower page than Fig. 6. It is on a short leaf that when allowed to rest on Fig. 6 will cover all the columns except the "Register No." The second page of this short leaf is shown in Fig. 8. This is for the notes on the second year. (Summary.) A second short leaf is used before we come to the full-sized page, (opposite of Fig. 6). This is for the records of the summary notes of the third and fourth years. Then we come to a full sized page used as a yearly-average comparison sheet. This is on the back of Fig. 6.

Individual Plant Registers. Figs. 9 and 10.*

With annual plants we have the whole story told in the growing plant. In the case of perennials, we need to follow the performance of individual plants throughout their lifetime and average the results in making our final selections of hardy, healthy, vigorous mothers of the coming generation. The plants are set so as to form rows running at right angles to one another. The rows in one direction are progenies or beds, and are given plot numbers. The rows in the other direction take care of the plant numbers in each progeny. The plant numbers are designated on their row stakes as decimals, hundredths. In this system, 35.92 stands for the 92nd. plant in the 35th row. When selections are made, this fits easily into our regular system, by prefixing the date that the nursery was set out, and omitting the decimal point. We have such a plant in an alfalfa nursery set out in 1909. If this plant should become a mother of a new strain, it would be designated as alfalfa 93592.

The individual plant register has one or more pages given over to a progeny. The opposite pages are duplicates. At the top of the page is found the register number and the year that this particular crop is grown. Each iine on the page takes care of a plant. The columns take care of the various notes that are taken. When the season's work is finished, summations of these plant records are made for each progeny and entered in the register of the crop in question (outlined above under head of "registers.") This enables us to compare the progenies from year to year. The individual plant registers of the different years enables one to look up the performance of any plant in question. The records of the more promising individuals are brought together on a summary sheet for final comparison.

NOTES.

Midsummer is a busy note-taking season with little more time than enough to carry out carefully laid plans. The notes to be taken vary with the kind of crop. Special registers are made out in winter, and

*For blank forms see pages 207-208.

the headings of these registers indicate the work to be done as the season advances.

In the case of alfalfa and clover, we are taking individual plant yields of hay and seed, and intend to follow the most promising of these plants to the field variety series. (In the case of alfalfa we hope to have a 1/100 acre series in 1911 where each plot has descended from a plant at the station.) In the case of the hay crop, each plant is tagged, cut and hung up on lines in the shade to dry. Later we get the dry weights on these plants. As no attempt was made to hang the plants in the order that they grew in the field, they are now considerably mixed. For this reason, a temporary record is made on a sheet of paper pinned to a small drawing board. The sheet is cross ruled so as to have as many lines as there are rows in the plot, and as many columns as there are plants in a row. A T-square enables one to find the proper places on the paper as fast as another can make the weights. From this sheet, the results are transferred to the register.

Before the seed crop is ripe, a list of superior plants has been made out from the records. Those that also prove to be good seed producers and tagged and hung on lines near our special individual thresher. When dry and time presents itself, these are weighed and threshed. The seed is stored in envelopes, 3 by 5½ inches open at the end. We use this size in all of our work. The envelopes are stored in tin boxes away from the mice.

Because of the fact that we annually make thousands of small weighings, we use a specially ordered spring dial scale. It weighs in grams from 2 to 800 with the pan on, or running up to 1,200 grams by taking off the pan. In the field this is hung on a tripod covered with a sheet to keep the wind from bothering. Indoors, the scale is often supported by a hook on the wires where plants are being weighed.

(Fig. 12 illustrates the scale in operation in alfalfa nursery.)

PLOTTING SYSTEM.

The plan of the perennial nurseries has been given. In the small grains, the first year selection plots are also planted in rows intersecting at right angles with not more than one plant in a hill, five inches each way. In variety testing, the plots are always long and narrow. A check is placed in the series frequently, and if seed and space will permit, the series is duplicated. The soil may seem uniform and yet the checks will show considerable variation. (Fig. 13 shows a portion of two grain series.) The yields are corrected to a uniform basis on a piece of coordinate paper. (Fig. 14.) The vertical lines represent the various plots of a series. The horizontal lines stand for different yields. Only each fifth line is shown. Four lighter lines run between each pair. The yields of the plots are now represented by small crosses properly placed. Circles are placed around those that represent the yields of the check plots. Lines are drawn to connect those in circles. This broken line gives the curve of soil fertility, as the check plots were planted with the same lot of seed. The adjacent vertical lines, (four between each of the heavier lines) represent the plots.

The adjacent horizontal lines represent pounds per plot. In selecting the land, we try to find a piece as nearly uniform as possible for this class of work to begin with. The accuracy of our scales, in weighing yields is usually half a pound. Therefore by using pound lines we can place a cross half way between two lines and proceed with as great accuracy as the scales.

An average is taken of the various yields of the check plots, and a horizontal line is drawn to represent that average. Dots are made on the vertical plot lines having the same relation to the line of average check as the crosses have to the curve. If a cross is five pounds above the curve of soil fertility, the corresponding dot is placed five pounds above the line of average fertility. If a cross is below the curve, the dot is placed the same distance below the line of average check yield. When these dots have been properly placed on all the plot lines, those representing adjacent plots are connected by straight lines. This gives us the yield curve, where the question of soil fertility has been taken out of consideration. Averages can now be made between duplicate plots to still further eliminate error. Three or more of these yearly averages should be had to give us a fair comparison among the strains in question.

(Fig. 15 illustrates the way the seed plots of cross-fertilized plants may be grouped.)

STAKES AND LABELS.

The stakes are two inches by one half-inch and two feet long. They are painted white freshly each year. The labels are plain white card

Fig. 1. A field of pedigree cowpeas No. 60901, crop 1909.

board, cut two by three inches. Waterproof drawing ink is used in making them out. The labels are dipped in hot paraffine to protect them from the weather. They are placed in the envelopes with the seeds that they represent. We try to know just where each plot is to go and the space it is to occupy before spring opens. We pick up an envelope of seed, and with it the label to be tacked on a stake. The stake follows the crop to the thresher and the label is placed in the top of the sack of seed. A tag with the same information is tied outside.

ACCESSION NUMBER BOOK.

KIND OF PLANT . . . .

Acession number.	Name of variety.	Source.	Date received.

Fig. 2.

ACCESSION NUMBER BOOK.

KIND OF PLANT..................

Amount received.	Date of entering nursery.	Remarks.

Fig. 3.

OAT BREEDING REGISTER.

MICH. EXP. STA.

Class......... *Season 19......*

Centgener Number.	N. stock number.	Plant number.	Accession number.	Description of plant selected.																						
				Straw.									Heads.							Grain.						
				Number of stalks.	Average height cm.	Uniformity %.	Stiffness gm.	Lodging %.	Color.	Rust resist-ance %.	Vigor %.	Weight of straw.	Number of heads	Spreading or close.	Erect or drooping.	Average length cm.	Uniformity %.	Smut Resist-ance %.	Shattering %.	Number of spikelets.	No. of grains in single hulls.	No. of grains in double hulls.	Yield gm.	Average wt. of grain.	Length of awn.	Color of grain.

Fig. 4.

OAT BREEDING REGISTER.

MICH. EXP. STA.

Class.......... *Season 19*......

Performance record in nursery plot 19......

Date planted.	Number of hills planted.	Stand %.	Vigor %.	Date heading.	Date ripe.	Lodging %.	Average height cm.	Rust resistance %.	Smut resistance %.	Number of plants harvested.	Yield of plot grams.	Yield per plant grams.	Nitrogen %.		Remarks.

Fig. 5.

ALFALFA BREEDING REGISTER.

MICH. EXP. STA.

			Description of parent plant.								
Register No.	Dam No.	Accession No.*	Height.	Width.	Leaves, N, M, W.	Date first cutting.	Date ripe.	Crop of year—	Total dry weight.	Mature seed.	Remarks.

Fig. 6.

ALFALFA BREEDING REGISTER.

MICH. EXP. STA.

	Date of seed planting.	Date plants were set out.	Average of first year notes (totals)														
								Dry weight.			Seed.		Corrected basis.			
			No. Hills.	Date cut.	No. living plants.	Height.	Width.	Total.	Per plant.	%Seeding.	Total.	Per plant.	Height.	Width.	Dry Wt.	Seed.

Fig. 7.

ALFALFA BREEDING REGISTER.

MICH. EXP. STA.

Average of second year notes (totals).

No. winter killed.	No. survivors.	Av. date first bloom.	Height.	Width.	Av. date ripe.	No. summer killed.	No. survivors.	Dry wt.		%seeding.	Seed		Corrected basis.			
								Total.	Per plant.		Total.	Per plant.	Height.	Width.	Av. dry wt.	Seed.

Fig. 8.

INDIVIDUAL ALFALFA REGISTER.

Year............ *Row No*............ *Register No*............

General characters.					1st cutting.				2d or seed cutting.				Totals.					
Plant number.	Height.	Width.	Leaf, N, M, W.		Date.	Green weight.	Dry weight.		Date.	Green weight.	Dry weight.		Dry weight.	Mature seed.				

Fig. 9.

INDIVIDUAL CLOVER REGISTER.

Year............ Row No............. Register No.............

General characters.										1st Cutting if before July 15.				2d or seed cutting.								
			Leaf.																			
Plant number.	Type, R. A. W.	Pubescent or G.	V. mottled or plain.	Mark light, medium or heavy.	Height.	Width.	Stems soft or woody.	Foliage light or dark.		Date.	Color of bloom.	Green weight.	Dry weight.	Date ripe.	Green weight.	Dry weight.	Weight of seed.	Color of seed.	Total dry weight.			

Fig. 10.

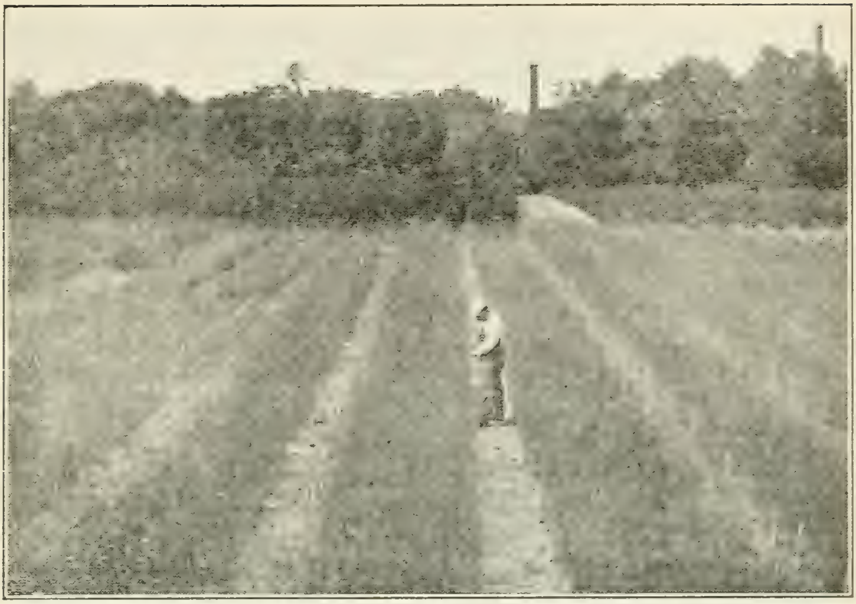


Fig. 11. Notetaking on centgener wheats, July, 1909.

Fig. 12. Spring dial scale. Obtaining green weights of individual alfalfa plants. June, 1909.

Fig. 13. Series of 1/100 acre wheat plots in foreground, and 1/20 acre oat series in background. Mostly from individual plants of 1906. Crop of 1909.

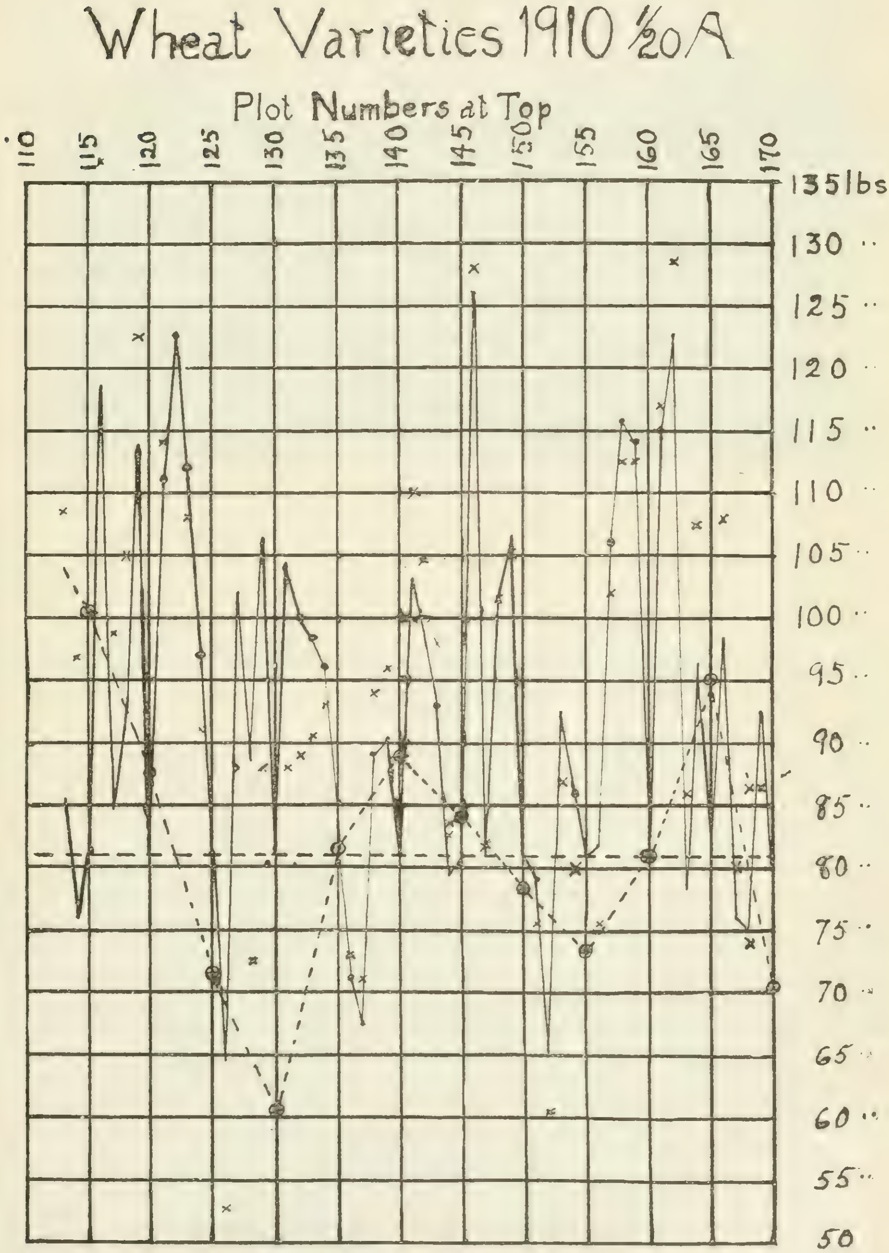

Wheat Varieties 1910 1/20 A
Plot Numbers at Top
110
115
120
125
130
135
140
145
150
155
160
165
170
135 lbs
130 ..
125 ..
120 ..
115 ..
110 ..
105 ..
100 ..
95 ..
90 ..
85 ..
80 ..
75 ..
70 ..
65 ..
60 ..
55 ..
50

Fig. 14.

Fig. 15.

A REPORT ON THE DAVENPORT ROTATION AND FERTILITY EXPERIMENT.

In 1890, at the request of Eugene Davenport, then Professor of Agriculture, the State Board of Agriculture appropriated $1,000 for draining and platting a series of plots for this experiment on the north side of field 5 or directly east of the present site of the college barns.

During the first five years of the experiment, 1891 to 1896, all the plots were devoted to uniform cropping as a means of comparing the fertility of the several plots. Then for ten years, 1896 to 1905 inclusive, the plots were planted in different rotations of crops or received different application of fertilizers and manure. After this ten year period, the plots were planted in the same crops for five years, 1906 to 1910, but the barley which was seeded in 1909 failed of a crop, because of a severe attack of nematodes and the clover seeded in the spring of 1910 failed to make a satisfactory stand. The small grain crops grown 1906 to 1908, however, would seem to give a fair comparison of the fertility of the several plots and are used for this purpose in this report.

Oats were grown in 1891,-'92-'94-'95 and wheat in 1893. Table I gives the annual and total yields of the several plots and will furnish some idea as to the relative fertility of the several plots when seeded to small grain, mostly oats. While the yields vary considerably, the totals, with one or two exceptions, do not vary more than would be expected on a Michigan soil of glaciated origin.

TABLE I.—*Yield per acre of plots in uniform cropping from 1891 to 1895.*

Plot numbers.	1891, oats.	1892, oats.	1893, wheat.	1894, oats.	1895, oats.	1891 to 1895, total oats and wheat.
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
1	1720	1480	1310	820	220	5550
3	1400	1570	1630	860	320	5780
5	1490	1490	1190	910	350	5430
7	1270	1390	1160	810	270	4900
17	....	1710	1610	1430	570	.....
19	1580	1840	1130	1150	370	6070
21	1650	1640	1370	970	310	5940
23	1700	1800	1100	1040	290	5930
25	2000	1740	1300	1210	270	6520
27	1900	1830	1300	1250	380	6660
29	1700	1720	1260	1230	250	6160
31	1310	1700	1010	1320	200	5540
34	....	1520	1050	880	250	....
36	....	1740	1200	980	320	....
60	1130	910	710	490	160	3400
62	1400	1120	1080	670	270	4540
64	1660	1330	1640	840	360	5830
66	1410	1290	1000	770	250	4720
68	1440	1260	1000	690	150	4540
70	1400	1270	1040	630	320	4660
72	....	1310	1160	....	210	....

Below is given the cropping (1896-'05) for those plots devoted to the study of the rotation of crops.

Plot 1—Wheat and clover.
Plot 3—Wheat, clover and corn.
Plot 5—Wheat, clover and potatoes.
Plot 7—Wheat continuously.
Plot 17—Beans continuously with rye seeding in fall and turned under in spring.
Plot 19—Beans continuously with rye seeded in fall and turned under in spring.
Plot 21—Corn continuously.
Plot 23—Orchard grass, continuously.
Plot 25—Orchard grass, continuously.
Plot 27—Corn continuously.
Plot 29—Fallow continuously.
Plot 31—Fallow continuously.
Plot 34—Clover continuously.
Plot 36—Wheat continuously.
Plot 60—Wheat continuously.

Plot 62—Wheat, clover and potatoes.
Plot 64—Wheat, clover and corn.
Plot 66—Wheat and clover.
Plot 68—Wheat continuously.
Plot 72—Clover continuously.

Table II gives such data in regard to yields of these plots (1896 to 1905) as is available.

TABLE II.—*Yield per acre of plots in rotation of crops from 1896 to 1905.*

Plot Nos	1896.		1897.		1898.		1899.		1900.	
		Pounds.		Pounds.		Pounds.		Pounds.		Pounds.
1...	Wheat.......	102	Clover.......	4970	Wheat.......	2460	Clover.......	......	Wheat.......	1350
3...	Wheat.......	171	Clover.......	5200	Corn (green)..	5450	Wheat.......	1170	Clover.......	4460
5...	Wheat.......	240	Clover.......	5090	Potatoes.....	......	Wheat.......	1040	Clover.......	3300
7...	Wheat.......	110	Wheat.......	1940	Wheat.......	1570	Wheat.......	1220	Wheat.......	......
17...	Beans........	1442	Beans........	1500	Beans........	290	Beans........	......	Beans........	......
19...	Beans........	1372	Beans........	1000	Beans........	360	Beans........	......	Beans........	......
21...	Corn.........	5300	Corn..	3750	Corn.	......	Corn.........	1700	Corn.........	2570
23...	Orchard grass.	......	Orchard grass.	3000	Orchard grass.	258	Orchard grass.	1750	Orchard grass.	2760
25...	Orchard grass.	......	Orchard grass.	3000	Orchard grass.	183	Orchard grass.	2250	Orchard grass.	3620
27...	Corn.........	6085	Corn.........	3860	Corn.........	......	Corn.........	210	Corn.........	3110
29...	Fallow......	....	Fallow.	...	Fallow....	.....	Fallow......	...	Fallow......	...
31...	Fallow.....	....	Fallow.....	...	Fallow.	.....	Fallow..	....	Fallow.....	....
34...	Clover.......	2240	Clover.......	4000	Clover.......	210	Clover.......	......	Clover.......	2350
36...	Wheat.......	105	Wheat.......	2050	Wheat.......	185	Wheat.......	920	Wheat.......	617
60...	Wheat.......	80	Wheat.......	......	Wheat.......	......	Wheat.......	900	Wheat.......	385
62...	Wheat.......	2620	Clover.......	4110	Potatoes.....	......	Wheat.......	640	Clover.......	1050
64...	Wheat.......	3440	Clover.......	5670	Corn.........	......	Wheat.......	612	Clover.......	4100
66...	Wheat.......	2300	Clover.......	5670	Wheat.......	2170	Clover.......	......	Wheat.......	722
68...	Wheat.......	157	Wheat.......	1590	Wheat.......	1980	Wheat.......	540	Wheat.......	487
70...	Fallow......		Fallow..	....	Fallow..	.....	Fallow.	...	Fallow.....	....
72...	Clover.......	2740	Clover.......	5110	Clover.......	2400	Clover.......	2300	Clover.......	3000

Plot Nos	1901.		1902.		1903.		1904.		1905.	
		Pounds.		Pounds.		Pounds.		Pounds.		Pounds.
1...	Clover..........	......	Wheat.........	2095	Clover.........	4300	Wheat.......	1460	Clover.......	3320
3...	Corn............	4020	Wheat.........	1610	Clover.........	4350	Corn.........	3100	Wheat.......	1160
5...	Potatoes........	5650	Wheat.........	2100	Clover.........	4600	Potatoes.....	4690	Wheat.......	1225
7...	Wheat..........	......	Wheat.........	730	Wheat.........	......	Wheat.......	980	Wheat.......	800
17...	Beans..........	......	Beans..........	850	Beans..........	490	Beans........	450	Beans........	210
19...	Beans..........	......	Beans..........	1150	Beans..........	500	Beans........	480	Beans........	210
21...	Corn............	1900	Corn...........	1200	Corn...........	2190	Corn.........	1730	Corn.........	602
23...	Orchard grass....	2150	Orchard grass...	1500	Orchard grass...	2230	Orchard grass.	2250	Orchard grass.	1640
25...	Orchard grass....	2900	Orchard grass...	2150	Orchard grass...	2970	Orchard grass.	2330	Orchard grass.	2620
27...	Corn............	2950	Corn...........	2700	Corn...........	2740	Corn.........	3500	Corn.........	322
29...	Fallow..	....	Fallow...	....	Fallow...	.....	Fallow..	....	Fallow.	.....
31...	Fallow......		Fallow.		Fallow.	....	Fallow ..	....	Fallow.	....
34...	Clover. ..	....	Clover ..		Clover		Clover....	.....	Clover.......	....
36...	Wheat..........	......	Wheat.........	1280	Wheat.........	1500	Wheat.......	1200	Wheat.......	680
60...	Wheat..........	......	Wheat.........	700	Wheat.........	1100	Wheat.......	460	Wheat.......	950
62...	Potatoes........	4500	Wheat.........	1170	Clover.........	2350	Potatoes.....	5110	Wheat.......	1340
64...	Corn............	3200	Wheat.........	1965	Clover.........	2650	Corn.........	4250	Wheat.......	2365
66...	Clover..........	......	Wheat.........	1775	Clover.........	2800	Wheat.......	1100	Clover.......	2250
68...	Wheat..........	......	Wheat.........	1100	Wheat.........	1290	Wheat.......	750	Wheat.......	690
70...	Fallow......	...	Fallow		Fallow		Fallow.	....	Fallow.....	
72...	Clover ...	....	Clover .	[illegible]	Clover..		Clover ..	..	Clover.......	

Table III gives the yields of corn 1906, oats 1907 and wheat 1908, after completion of the ten-year period of special cropping.

TABLE III.—*Yield per acre of plots in uniform cropping after ten years in rotation of crops.*

Plot numbers.	Rotation during 10 year period.	1906, corn.	1907, oats.	1908, wheat.	1906, 1907, 1908, total corn, oats and wheat.
		Pounds.	Pounds.	Pounds.	Pounds.
1	Wheat and clover	4800	1000	1760	7560
3	Wheat, clover and corn	4060	720	1650	6430
5	Wheat, clover and potatoes	5070	880	1600	7550
7	Wheat, continued	3560	590	1110	5260
17	Beans, continued, with rye	5390	880	870	7140
19	Beans, continued, with rye	4720	770	980	6470
21	Corn, continued	2340	860	1330	4530
23	Orchard grass, continued	5910	1070	2070	9050
25	Orchard grass, continued	5890	1250	2120	9260
27	Corn, continued	3740	1120	2000	6860
29	Fallow	5100	950	1460	7510
31	Fallow	5060	950	1900	7910
34	Clover, continued	4260	660	1800	6720
36	Wheat, continued	3490	550	1080	5120
60	Wheat, continued	4280	520	730	5530
62	Potatoes, wheat and clover	5380	640	1000	7020
64	Corn, wheat and clover	5770	950	1530	8050
66	Wheat and clover	5200	900	1270	7370
68	Wheat, continued	4420	610	1110	6140
70	Fallow	3590	740	1140	5470
72	Clover, continued	5020	850	1420	7290

Table IV is compiled from Table III and gives the average yields of certain plots which had received the same treatment.

TABLE IV.—*Average yield per acre of duplicate plots planted in uniform crops, during 1906-'07-08, after 10 years in rotation of crops.*

Plot numbers.	Rotation during 10 year period.	1906, corn.	1907, oats.	1908, wheat.	1906, 1907, 1908, total corn, oats and wheat.
		Pounds.	Pounds.	Pounds.	Pounds.
1 and 66	Wheat and clover	5000	950	1510	7460
3 and 64	Wheat, clover and corn	4810	830	1590	7240
5 and 62	Wheat, clover and potatoes	5220	760	1300	7280
7, 36, 60 and 68	Wheat, continued	4314	575	1042	5597
29, 31 and 70	Fallow, continued	4335	845	1410	6590

As the duplication of some of the treatments were on adjacent plots and some on plots varying in fertility and some distance from each other, it was not possible to include data from all the plots in the above table.

In Table V (compiled from Table III) is given the yields from the various treatments in the first series of plots.

TABLE V.—*Yield per acre of plots in first series, planted in uniform crops, during 1906-'07-'08, after 10 years in rotation of crops.*

Plot numbers.	Rotation during 10 year period.	1906, corn.	1907, oats.	1908, wheat.	1906, 1907, 1908, total corn, oats and wheat.
		Pounds.	Pounds.	Pounds.	Pounds.
1	Wheat and clover	4800	1000	1760	7560
3	Wheat, clover and corn	4060	720	1650	6430
5	Wheat, clover and potatoes	5070	880	1600	7550
7	Wheat, continuously	3560	590	1110	5260
17 and 19	Beans, continuously, with rye	5050	820	820	6800
21 and 27	Corn, continuously	3040	990	1660	5690
23 and 25	Orchard grass, continuously	5900	1160	2090	9150
29 and 31	Fallow, continuously	5080	950	1680	7710

It is unfortunate that more data in reference to this experiment has not been preserved. Some difficulty was experienced in getting good stands of clover, the small grain plots were several times seriously attacked by sparrows and other circumstances tended to lessen the value of the experiment. The notes taken of the experiment were also very limited and in many cases the yields were not determined or were lost. It is therefore, not possible to state definitely in all cases the yields during the ten-year rotation period and to make a comparison of the different treatments on a profit and loss basis and to work out other data which should be very valuable in an experiment of such long standing.

However, in studying the preceding tables, it may be said that (not considering the immediate profit or loss from the various treatments) the data indicate that:

(1) A wheat and clover rotation has a somewhat better effect upon the fertility of the soil than wheat, clover and corn, or wheat, clover and potatoes. The first mentioned rotation includes clover every second year or one-half the time and would be expected to have a better effect upon the fertility of the land than the other rotation mentioned in which there is clover every third year. However, the differences are not marked. Wheat, clover and potatoes have produced slightly better results than wheat, clover and corn.

(2) That the above mentioned rotations in which clover appears give better results than when land is continuously cropped in wheat or corn, the plots which had been planted in wheat and clover having about one-third greater producing power than those which had been seeded continuously to wheat or corn.

(3) That beans grown each season with rye seeded in fall and turned under in spring as a green manure crop has a better effect on the fertility of the soil than growing corn continuously in this test increasing the production 21% above the corn plot. The bean plots also show an increase of 29% above the continuous wheat plot but by turning to Table I, it will be seen that Plot VII upon which this comparison was made did not possess the original fertility of the other plots. The planting of beans continuously with rye as a green manure crop while not as good as the clover rotations compares fairly well with them.

(4) That continuous cropping in orchard grass tends to increase

the crop producing power of the soil in this instance showing an increase of 18½% over the next highest yield and 21% over the wheat and clover rotation. This was doubtless due largely to the heavy root system produced which stored up considerable plant food in vegetable form, that become available again soon after breaking. The better physical condition produced by the heavy sod doubtless had much to do with the increased production.

(5) While the plots in the first series which had been fallowed for 10 years, produced more than any of the other plots of the series, except those which had been in orchard grass, when the averages of both series are considered, the yields are considerably lower than after the rotations including clover, the wheat and clover showing an increase of 1.32% above the yield after the fallow. This possibly has been due to the manufacture during the summer season of available nitrates which have been washed from the soil since no crop was permitted on the plots to utilize them.

In the second part of the experiment which was devoted to the testing of commercial fertilizers all the plots were planted in uniform crops from 1891 to 1898 evidently with the original idea of securing data for a preliminary comparison of the several plots. The cropping during this period and the yields from the several plots, which will give some idea of their relative fertility, are shown in Table VI. The only instance during the eight years in which the several plots seem to have been accorded a different treatment was in 1894 when commercial fertilizers were applied as follows: Plot 2, 10 loads per acre of manure; plot 4, 100 pounds per acre of dissolved bone; plot 14, 100 pounds per acre of ground bone; plot 16, 50 pounds per acre of sulphate of ammonia; plot 18, 100 pounds per acre of Homestead fertilizer; plot 20, nothing; plot 22, 100 pounds per acre of muriate of potash; plot 24, 95 pounds per acre of common salt; plot 26, 15 bushels per acre of wood ashes; plot 28, 100 pounds per acre of Lister's Success fertilizer; plot 30, 100 pounds per acre of nitrate of soda; plot 32, 50 pounds per acre of sulphate of ammonia.

From 1899 to 1905 fertilizers were applied annually to the several plots as indicated in Table VII. The mixed commercial fertilizer at first used was a sugar beet special but this was later changed to another of the same analysis, viz.: Armour's Fruit and Root Crop Special which has a guaranteed analysis as follows: Nitrogen, 1.65%; available phosphoric acid, 8.00%; potash, 5.00%. During the seven-year period in which the fertilizers were applied the plots were cropped lengthwise of the series or across all the plots, with various crops in narrow strips, varying from about 22 feet to 44 feet in width largely according to the number of strips. The available notes however do not indicate the order of planting of these strips, or in all cases the exact width so that it is impossible to determine the order of cropping of any portion of the series, or to determine the yield per acre of any of the crops, or to check up the data on a profit and loss basis. In Table IX is given the yield per acre from the several plots in uniform cropping during 1906, 1907 and 1908, following the seven-year period during which the fertilizers were applied. Table X prepared by Director C. D. Smith gives the total amount of nitrogen, phosphoric acid, and potash removed in crops and applied in fertilizers from 1899 to 1905 inclusive.

On account of the uncertainity as to the order of cropping and the lack of definite data as to size of the subdivisions of plots, the writer is unable to draw many practical conclusions from the above data, but the same is published in the hope that it will be of interest to others and also as a matter of record.

TABLE VI.—*Yield of plots in uniform cropping from 1891 to 1898.*

Plot numbers.	1891, oats.	1892, oats.	1893, wheat.	1894, wheat.	1895, *	1896, wheat.	1897, clover.	1898, clover.	1891 to 1898, total.	
									Grain.	Clover.
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
2	1240	1350	1010	1730	....	1300	6380	4490	6630	10870
4	1310	1390	1200	1260	....	770	6580	4830	5930	11410
14	1320	1480	1650	1520	....	780	6130	4880	6750	11010
16	1330	1340	1280	1760	....	820	6190	4910	6530	11100
18	1250	1420	1400	1300	....	670	7360	4900	6040	12260
20	1350	1410	1240	1340	....	490	6560	4940	5830	11500
22	1340	1380	1010	1310	....	450	7200	4670	5490	11870
24	1400	1420	1210	1320	....	500	7240	4680	5850	11920
26	1370	1420	1110	1300	....	450	7250	4530	5650	11780
28	1330	1380	1050	1080	....	550	6920	4330	5390	11450
30	1660	1350	1040	1540	....	620	7380	4950	6210	12330
32	1250	1500	1000	1130	....	440	7470	4170	5320	11640

*In 1895 the series was seeded to clover but a poor stand was secured and was broken up in July, and summer fallowed for the remainder of the summer and seeded to wheat in the fall.

TABLE VII.—*Yields from Fertilizer plots from 1899 to 1905.*

Plot No.	Fertilizer applied annually during seven year period.	1899.				1900.							1901.			1902.					1903.			1904.				1905.			
		Sugar beets.	Potatoes.	Beans.*	Corn.	Oats.	Wheat.	Beans.	Corn.	Potatoes.	Sugar beets.	Turnips.†	Potatoes.	Beans.	Sugar beets.	Wheat.	Potatoes.	Corn.	Sugar beets.	Sugar beets.	Beans.	Potatoes.	Corn.	Corn.	Sugar beets.	Beans.	Potatoes.	Potatoes.	Corn.	Sugar beets.	Beans.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
2	20 tons stable manure	373	88	..	39	25	9	41	66	71	781	261	101	46	285	39	140	65	660	955	24	182	150	133	702	20	173	291	114	725	33
4	240 lbs. acid phosphate	281	76	....	43	31	8	31	61	47	466	221	58	46	191	45	103	70	409	715	12	129	126	111	445	23	110	163	78	251	10
14	120 lbs. nitrate of soda; 240 lbs. acid phosphate	303	70	....	43	26	15	35	75	32	588	204	47	46	302	46	98	60	691	667	15	158	135	82	623	19	126	137	86	686	15
16	120 lbs. nitrate of soda; 120 lbs. muriate of potash	322	75	....	46	28	12	33	73	35	605	171	50	46	315	41	115	70	810	690	19	130	98	80	610	20	126	197	91	702	20
18	480 lbs. mixed commercial	342	66	....	41	28	16	26	78	34	605	232	53	52	248	54	105	60	572	763	20	144	106	104	496	22	113	146	75	624	20
20	None	325	67	....	45	28	12	16	53	38	490	198	36	31	190	33	86	65	488	574	17	115	79	81	441	16	92	196	72	461	11
22	120 lbs. muriate of potash	357	69	....	43	32	10	23	64	45	573	199	51	46	245	24	92	55	484	655	17	130	76	88	506	14	101	213	82	532	10
24	120 lbs. nitrate of soda; 240 lbs. acid phosphate; 120 muriate of potash	397	84	....	42	30	16	22	84	38	671	265	50	44	333	51	108	85	647	885	19	172	90	134	731	19	129	213	88	573	18
26	240 lbs. acid phosphate; 120 lbs. muriate of potash	335	80	....	37	36	14	25	78	38	652	189	41	42	265	59	116	65	738	765	16	138	99	127	632	15	102	242	109	585	16
28	240 lbs. nitrate of soda; 240 lbs acid phosphate; 120 lbs. muriate of potash	337	56	....	42	28	15	19	76	35	683	231	48	70	304	54	111	80	598	890	22	120	100	130	691	16	88	175	106	615	12
30	120 lbs. nitrate of soda	329	59	..	41	31	13	22	66	37	550	209	25	40	238	35	101	55	576	637	17	97	75	89	547	11	72	117	84	496	8
32	100 lbs. sulphate of ammonia; 240 lbs acid phosphate; 120 lbs. muriate of potash	335	60	....	46	30	17	24	76	40	617	174	46	45	219	58	142	75	608	768	22	143	105	122	647	15	110	198	91	619	15

*No records of the yields of beans in 1899 are available.
†In 1900 turnips were grown between the rows of corn.

TABLE VIII.—*Total yields from fertilizer plots from 1899 to 1905 inclusive.*

Plot Nos.	Fertilizer applied per acre annually during seven year period, 1899 to 1905.	Beets.	Potatoes.	Corn.	Stalks.	Oats.	Wheat.	Straw.	Beans.	Pods.	Turnips.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Lbs.
2	20 tons stable manure	4492	1046	567	609	25	48	146	164	127	261
4	240 lbs acid phosphate	2758	686	489	498	31	53	110	122	83	221
14	120 lbs. nitrate of soda; 240 lbs. acid phosphate	3860	668	481	438	26	61	101	130	87	204
16	120 lbs. nitrate of soda; 120 lbs. muriate of potash	4054	728	458	437	28	53	110	138	97	171
18	480 lbs. mixed commercial	3650	661	464	446	28	70	85	140	99	232
20	None	2969	630	395	416	28	45	78	91	78	171
22	120 lbs. muriate of potash	3352	701	408	402	32	34	78	110	80	199
24	120 lbs. nitrate of soda; 240 lbs. acid phosphate; 120 lbs. muriate of potash	4237	794	523	460	30	67	116	122	95	265
26	240 lbs. acid phosphate; 120 lbs. muriate of potash	3972	757	515	521	36	73	86	114	80	189
28	240 lbs. nitrate of soda; 240 lbs acid phosphate; 120 lbs. muriate of potash	4148	633	534	461	28	69	126	139	103	238
30	120 lbs. nitrate of soda	3373	508	410	396	31	48	103	107	85	209
32	100 lbs. sulphate of ammonia; 240 lbs. acid phosphate; 120 lbs. muriate of potash	3843	739	516	554	30	75	105	122	94	174

TABLE IX.—*Yields per acre of plots in uniform cropping after seven annual applications of fertilizer.*

Plot Nos.	Fertilizer applied per acre annually during seven year period, 1899 to 1905.	1906, corn.	1907, oats.	1908, wheat.	1906, 1907, 1908, total corn, oats and wheat.
		Pounds.	Pounds.	Pounds.	Pounds.
2	20 tons stable manure	539	126	177	842
4	240 lbs. acid phosphate	461	87	135	683
14	120 lbs. nitrate of soda; 240 lbs. acid phosphate	449	97	147	693
16	120 lbs. nitrate of soda; 120 lbs. muriate of potash	502	93	154	749
18	480 lbs. mixed commercial	452	91	213	756
20	None	383	70	135	588
22	120 lbs. muriate of potash	484	78	186	748
24	120 lbs nitrate of soda; 240 lbs. acid phosphate; 120 lbs. muriate of potash.	536	122	172	830
26	240 lbs. acid phosphate; 120 lbs. muriate of potash	518	83	160	761
28	240 lbs. nitrate of soda; 240 lbs. acid phosphate; 120 lbs. muriate of potash.	462	145	228	835
30	120 lbs. nitrate of soda	383	99	146	628
32	100 lbs. sulfate of ammonia; 240 lbs. acid phosphate; 120 lbs. muriate of potash	520	123	158	801

TABLE X.—*Total amount of nitrogen, phosphoric acid and potash removed in crops and applied in fertilizers from 1899 to 1905 inclusive.*

Plot Nos.	Removed in crops.				Applied in fertilizer.		
	Nitrogen.	Phosphoric acid.	Potash.	Dry matter.	Nitrogen.	Phosphoric acid.	Potash.
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
2	39.15	14.08	34.14	2891.45	110.25	72.05	145.50
4	29.59	10.52	30.66	1581.91	....	27.88	....
14	31.71	11.52	35.10	1681.00	13.44	27.88	....
16	32.20	11.68	34.34	1722.87	13.44	....	36.96
18	31.75	11.74	34.52	1672.21	8.70	39.75	22.17
20	26.92	9.73	29.71	1441.10	....	....	....
22	27.58	10.05	31.37	1401.84	....	....	36.96
24	33.75	12.36	38.34	1832.82	13.44	27.88	36.96
26	32.84	11.98	36.48	1387.47	....	27.88	36.96
28	33.92	12.47	37.56	1827.87	26.88	27.88	36.96
30	27.41	9.95	30.76	1477.24	13.44	....	....
32	29.04	12.14	35.11	1767.12	14.63	29.86	36.96

Respectfully submitted,
V. M. SHOESMITH,
Farm Crops Experimentalist.

East Lansing, Mich., June 30, 1911.

BULLETINS

OF THE

AGRICULTURAL COLLEGE EXPERIMENT STATION

ISSUED DURING THE

YEAR ENDING JUNE 30, 1911.

FOREWORD.

Bulletin No. 262.

This bulletin has been prepared to meet the constant and growing demand for information on the general subject of planting orchards in Michigan. It has been written by Mr. O. K. White, Field Agent in Horticulture, and is based upon his experience and observations as a successful fruit grower.

In the discussion of varieties an effort has been made to avoid technical terms in describing the tree and fruit, and to mention such merits, faults and peculiarities of the varieties as may be useful to any one who has to decide the important question of selecting them. The list presented has been carefully examined and approved by Mr. Benton Gebhardt, of Hart, Oceana county, one of the most successful and experienced fruit growers in Michigan.

H. J. EUSTACE,
Horticulturist.

SITE AND SOIL FOR AN ORCHARD.

The success and profitableness of an orchard depends so largely upon the site and soil that it behooves the prospective fruit grower to give to these features careful consideration, before he ventures into the business.

The site for an orchard should not be low or level, but should be more or less rolling and have an elevation somewhat higher than is common to the vicinity or section. Such a site supplies good air drainage. Cold air is heavier than warm air and always sinks to lower levels, hence low grounds are more subject to frosts and severe winter freezing. Such disastrous results as occurred at the time of the February freeze of 1899 and the October freeze of 1906, are still fresh in the minds of many Michigan fruit growers who had orchards on low, level lands. Many of the orchards, which had until these times been very successful, were practically destroyed. Even on higher lands, pockets must be avoided because cold air settles in them and cannot get out. It is not necessary that a site be extremely hilly or that the orchard be located upon high hill tops. In many cases it would be better to avoid hill tops on account of their exposure to winds and their tendency to severe soil washing. Abrupt hillsides should also be avoided because of the difficulties encountered in spraying, tillage and harvesting.

The slope and exposure of a site has some bearing upon its desirability for the planting of an orchard. Generally a south slope has a lighter soil and warms earlier in the spring than a northern or eastern exposure. This induces earliness in blossoming and ripening of fruit, which is sometimes desirable. On the other hand, trees on a southern exposure are much more subject to winter killing and sunscald. Generally, northern or eastern exposures are preferred by fruit growers, because they usually have strong soils, are more retentive of moisture, and are not so susceptible to winter injury or late spring frosts.

It must be understood that some fruits are hardier than others. The apricot is so tender that it seldom does well in Michigan. As long as winters are mild it may do fairly well, but it is almost certain to be killed by the first severe winter, even though planted on the most favorable location. The peach is nearly as tender, while the plum follows very closely. Apples, pears and quinces are not as tender or as sensitive to extremes of cold as peaches and plums, and hence it is not as imperative that they be given such careful consideration in the location of a site for an orchard. Their blossoming later in the spring is also another point in their favor.

The different fruits require different types of soil, but all do their best on a strong, deep, well-drained soil. Trees cannot thrive upon soils that are depleted, shallow, or poor in texture, where an impervious hardpan is near the surface, or where they have "wet feet." Examples of

failures, due to these conditions, are not uncommon. Stunted trees, or blank spaces in the low spots of an orchard usually indicate poor soil drainage or poor air drainage or both. Artificial drainage may sometimes be resorted to, in order to make a location suitable for an orchard, but ordinarily such a procedure is not satisfactory, especially in a commercial orchard. For a home orchard, which it is highly desirable to have near the house, artificial drainage may be frequently used to take advantage of a desirable location.

A soil can be too dry for fruit trees. Such is the condition of some of Michigan's sandy soil, which is so porous and devoid of humus that it cannot retain moisture. Trees on such soil invariably lack in vigor, productivity and hardiness. In the case of peaches.* "Either extreme of moisture—excessive wetness or excessive dryness—gives favorable conditions for winter killing. The wet soil is conducive to sappiness in a tree, and also freezes deeply. Severe cold, especially if alternating with warm weather, or accompanied with dry winds, causes evaporation of water from the trees, and if the soil be so dry as not to furnish moisture to replace the evaporated water, harmful results ensue."

The soil that is shallow, or devoid of plant food, cannot be expected to produce an orchard and keep it in vigorous health and productivity. While plant food can be added to the soil, it is a factor which the orchardist must not overlook or underestimate, because it is just as necessary that an orchard produce a good strong growth in the first few years of its existence as after it comes into bearing. Scores of orchards in Michigan, today, are unhealthy and unproductive simply because they were planted upon soils deficient in plant food.

Soils best adapted to apples may vary from a rich, sandy loam to a clay loam, while pears prefer a clay loam or a pure clay, provided it is of a good texture. Plums and cherries usually do best on a medium loam, and peaches on a soil ranging from a sandy nature to a medium clay loam. While it is conceded that the nature of a soil may be influenced greatly and its adaptability to different fruits made possible to a greater or less extent by the use of lime, manures and commercial fertilizers, yet it is important to emphasize the wisdom of selecting a soil best suited to the fruit that is expected to be raised, or to plant only those fruits best suited to the soil one already has.

PREPARATION OF SOILS FOR AN ORCHARD.

The preparation of soil previous to the planting of an orchard will depend entirely upon its nature, its texture and its condition of fertility. It is generally agreed that a field should be brought into the best possible state of cultivation before it is planted to fruit trees. If young trees are planted in a soil that is not in a condition to induce a strong, vigorous, healthy growth, throughout the first few years of their lives, the orchard will never be as healthy, productive, or bring as good returns as it would have done if the trees had been given a good start,

*Hedrick, U. P., Mich. State. Hort. Soc. Rept. 1907, p. 56.

and the lack of clean and thorough cultivation previous to planting the trees makes it much more difficult and expensive after the trees are planted. Not only should the preparation of soil be clean and thorough, but it should be deep. The soil should be loosened up as deeply as possible with the plow. On some soils it is highly desirable to use the subsoil plow, running it to a depth of from 16 to 20 inches. Soils which are naturally loose and subject to leaching would be possible exceptions, and should be treated in a way to avoid leaching.

While it is not desirable to select for an orchard, soils which need artificial drainage, yet if such is chosen, it should be underdrained with tile. Since trees are intended to occupy the land for a longer period of time than ordinary crops, the grower can afford to give the soil better preparation than for ordinary annual crops.

In most cases it will be a decided advantage to devote the land to hoed crops, such as potatoes, corn or beans for one or two years, before planting the orchard, so that all weeds can be subdued and the soil worked into a good condition. At the same time, any poor portions of the field can be easily located and improved. If the soil is badly depleted, it would be advisable to seed it to clover and turn under the sod before planting. If the trees are to be planted in the spring, it is better to plow the soil in the fall, unless the slope is such as to wash badly. The alternate freezing and thawing during the winter will assist greatly in pulverizing and mellowing the soil.

FALL OR SPRING PLANTING.

The advisability of fall or spring planting depends upon several conditions. Fall planting has the advantage over spring planting in that the trees become firmly established in the soil before winter sets in, and are able to start growth in the spring before the ground can be marked and put into condition for planting. This is important because the trees get a good growth in the early part of the season, before the summer drouths occur. On the other hand, there is more or less danger from winter injury during a severe winter or from the drying out of the trees if the winter is long and dry. Fall planting is much more successful with the hardy apples and pears than it is with the tender plums, cherries and peaches. In Michigan, it is seldom safe to plant peaches sweet cherries, or apricots in the fall.

The convenience of the season will determine in a majority of cases whether or not the planting shall be done in the fall or spring. Very often the rush of spring work induces the grower to hurry his planting, or to do it carelessly, and as a result a poor stand is secured, with crooked rows. Others have large crops to harvest in the fall, and would find it more convenient to do the planting in the spring. If there is any doubt as to the best time to plant, let it be done in the spring, and as early as the ground can be gotten into proper condition.

DISTANCE FOR PLANTING.

Most of the old Michigan orchards, especially of apples, were planted too close. Trees produce not only large tops, but develop extensive root systems and are wide feeders. They should be planted far enough apart so that they will not interfere with each other, or if planted more closely than the proper distance, the plantings should be done in such a way as will later permit a judicious thinning of the trees. Another disadvantage in planting trees too close together is the serious difficulty which will be encountered in the operations of spraying and cultivating. In orchards where trees are close together not only is the spraying more difficult, but diseases and insects thrive more easily. For the same reasons the outside rows should not be located too near the fence.

The distance apart that fruit trees should be planted depends not only upon the kind of fruit to be raised, but in many cases upon the variety. Some varieties differ greatly in vigor and habits of growth from others, and requires greater distances; for example, the Northern Spy apple as compared with the Wagener, the Crawford peach as compared with the Gold Drop, the Grand Duke plum as compared with the Wixom. Trees planted upon strong soils require greater distances than on lighter soils, because they will usually live longer and make a much more vigorous growth of top and root. However, if the grower has clear and definite plans to do repressive pruning, he may reduce the standard distances somewhat. Close planting should not be attempted unless a man knows how and is sure to continue his practice of heading-in the trees every year.

Safe distances for planting under ordinary and normal conditions in Michigan are:

Apples, 33-40 feet, or even 45-50.
Standard pears, 20-25 feet.
Dwarf pears, 10-12 feet.
Peaches, plums and apricots, 20-24 feet.
Sweet cherries, 25-40 feet.
Sour cherries, 18-24 feet.
Quinces, 10-12 feet.

DOUBLE PLANTING AND FILLERS.

There are few farmers who care to or can afford to plant an orchard, cultivate, prune and fertilize it properly without getting back some returns for the investment and labor before the trees produce profitable crops. This difficulty may be overcome by growing shorter lived fruits, such as raspberries, strawberries, currants, gooseberries, or such annual, cultivated crops as corn, beans, potatoes, or peas, among the trees. If such a plan is adopted, the owner should realize that he must make greater efforts to conserve the moisture and fertility of the soil, or his

orchard will permanently suffer. The planting of bush fruits is seldom advisable in a large commercial orchard, for they interfere so seriously in so many orchard operations, especially spraying. The using of fillers or early bearing and maturing varieties should not be undertaken by any except those who are determined and willing to remove them when they begin to crowd the permanent trees, or when the permanent trees come into full bearing.

Pears should seldom be planted among apples, as they require radically different methods of cultivation. Peaches or plums are being largely used as fillers, and with considerable success on favorable locations. Their usefulness is about over at 12 or 15 years, but even if not, they should be removed for convenience in caring for the orchard, and to avoid crowding the permanent trees.

If apples are to be used as fillers, such early bearing varieties as Wagener, Grimes, Duchess, Wealthy, or Yellow Transparent, may be used, and then it would be well to plant the permanent trees somewhat farther apart than common.

MIXED PLANTING.

Many varieties will not bear well when planted alone, or in large blocks.

This is because they require the pollen from blossoms of other varieties. Inasmuch as all varieties benefit by cross pollination, it is a good thing to plant four or five rows of one variety and then four or five rows of another, and so on. If the orchardist finds his trees barren from lack of cross-pollination, he may graft every fourth or fifth tree of every fifth row to some variety having commercial value, blossoming at the same time and having an affinity for the barren variety.

*STERILE AND SELF-FERTILE VARIETIES.

Apples more or less self-sterile: Belleflower, Chenango, Gravenstein. King, Northern Spy, Primate, Roxbury Russett, Spitzenburg, Tolman.

Varieties mostly self-fertile: Baldwin, Greening, Duchess of Oldenburg, Red Astrachan, Yellow Transparent.

Varieties of pears more or less self-sterile: Duchess, Anjou, Bartlett, Clairgeau, Clapp, Howell, Jones, Kieffer, Lawrence, Louise, Mount Vernon, Sheldon, Superfin, Winter Nelis.

Varieties generally self-fertile: Bosc, Manning Elizabeth, Seckel, Kieffer.

Varieties of plums more or less self-sterile: Coe, Fellenberg, Satsuma.

Varieties generally self-fertile: Burbank, Lombard, Damsons, Bradshaw.

*Bailey's Principles of Fruit Growing, page 229.

TREES TO PLANT.

It is by all means advisable to secure first-class trees. Such trees should be medium in size for their age, free from injurious insects and diseases, should have a healthy root system, with enough good-sized roots to hold the tree firmly in the soil and a good lot of fine roots. Not all varieties have straight trunks, and this should be taken into consideration. Large sized trees should not be considered first-class and should be avoided, as often much of their root system is removed in digging, and they adapt themselves to new conditions with greater difficulty. The extra expense necessary to buy first-class nursery stock will be many times repaid before the trees have outlived their usefulness. It is usually preferable to secure trees from a nearby reliable nurseryman. His soil and climatic conditions are more apt to be like those of the field in which the trees are to be set. The trees are thus saved the unnecessary effort of adapting themselves to new and radically different conditions. However, the importance of this point is doubtless overestimated, as many distant nurserymen may have practically identical soils and climates. Other advantages of patronizing nearby nurserymen are the saving of expense in shipping and avoiding the danger of injury in transit. Then, too, the purchaser can visit the nursery and select his trees, and be more certain to secure what he desires. There is doubtless considerable advantage to the orchardist in furnishing the nurseryman with scions or buds secured from trees of known productiveness, hardiness and health.

There is a growing tendency on the part of orchardists to demand younger and smaller trees. In doing so, they can better shape the top to their desire, retain a much larger part of the root system, and secure a better and more certain growth. Young trees will usually grow faster and more vigorously than older ones. The age at which trees should be preferred from the nursery are: apples, quinces and pears, 2 to 3 years; peaches and sweet cherries, 1 year; plums and sour cherries, 1 to 2 years. There is no material difference between budded and root grafted trees, provided they are of the same size and vigor, except, perhaps, in the North Peninsula, where it would be advisable to get root-grafted apple trees, and secure stock of known hardiness.

The use of dwarf trees is usually confined to pears. While more dwarf trees can be planted upon an acre, and larger fruits can be produced, still they have not found favor among commercial orchardists except in a few sections where an extra high grade of fruit is desirable. Dwarf trees are secured by propagating upon a slow growing root, but will not remain dwarf unless severely headed-in every year.

As soon as the trees are received from the nursery they should be carefully heeled-in the ground, as near the field intended for the orchard as possible, and preferably at the north side of a building or wood lot, especially in the spring, in order to protect them from the sun, keep them cool and retard their development. The trench should be dug

sufficiently deep to receive all the roots. The trees should be carefully laid in, with their tops to the south, then fine, moist soil should be put between the roots, so that no air spaces are left. If trees are to be left heeled-in during the winter, care should be taken to remove all packing material which could harbor mice, rats or rabbits, and then snow should be kept over them as a protection from severe cold.

SYSTEMS OF ORCHARD PLANTING.

There are several systems of orchard planting,—the square system, in which the trees are set at the corners of a square, making the rows equidistant in both directions; the quincunx system, which is the same as the square system, except that a tree is planted in the center of the square, and the hexagonal or equilateral triangular system, in which the trees are equidistant apart in all directions.

Of these, the square system is the most commonly used. While it does not permit of planting as many trees per acre as the other systems, it has the advantage of being easily laid out, is the easiest to cultivate and permits of systematic and definite thinning when the trees begin to crowd each other.

P	P	P	P
P	P	P	P
P	P	P	P
P	P	P	P

Square system.

P	F	P	F	P	F	P
F	F	F	F	F	F	F
P	F	P	F	P	F	P
F	F	F	F	F	F	F
P	F	P	F	P	F	P
F	F	F	F	F	F	F
P	F	P	F	P	F	P

Square system with fillers.

It is easily modified into the rectangular system, in which the rows are farther apart in one direction than the other.

The quincunx system permits of the planting of a great many more trees per acre than the square system. The number per acre will be increased from 45% in small orchards to 98% in large orchards. The ad-

P		P		P		P
	P		P		P	
P		P		P		P
	P		P		P	
P		P		P		P
	P		P		P	
P		P		P		P

Quincunx system.

P	F	P	F	P	F	P
F	P	F	P	F	P	F
P	F	P	F	P	I	P
F	P	F	P	F	P	F
P	F	P	F	P	F	I
F	P	F	P	F	P	F
P	F	P	F	P	F	P

Quincunx system with fillers.

vantages of this system are similar to those of the square system. The popularity of both is due to the possibility of planting the trees quite thickly, and of thinning with a fair degree of success at what ever distance the trees are set. In such cases early bearing and maturing trees should be used as fillers and planted intermediately between the permanent trees. As indicated in the diagrams, the first proper thinning of the square system is performed by removing every other tree and alternating in the rows, and leaving the orchard in the quincunx system. This in turn may be thinned by removing the central tree, leaving the orchard in the square system again. Thus an orchard set 20 feet square, when properly thinned, leaves the trees 40 feet quincunx or in squares 28.28x28.28 feet, running diagonally across the field. This, properly thinned, leaves the trees in squares 40 feet apart.

The hexagonal or equilateral triangular system is popular because it distributes the trees evenly over the field and permits of planting the greatest number of trees per acre at a good distance apart. Approximately 15% more trees per acre may be planted. While it has this advantage, it has also the disadvantage of inconveniencing all cultivation, especially in the turning at the ends of the rows and the necessity of finishing up the corners, and also the impossibility of permitting any

	P		P		P		P
P		P		P		P	
	P		P		P		P
P		P		P		P	

Hexagonal system.

	P	F	P	F	P	F	P	F
F	F	F	F	F	F	F	F	
	F	P	F	P	F	P	F	P
F	F	F	F	F	F	F	F	
	P	F	P	F	P	F	P	F
F	F	F	F	F	F	F	F	
	F	P	F	P	F	P	F	P

Hexagonal system with fillers.

satisfactory method of thinning the trees without removing too large a proportion of them. When this system is used, and the trees are planted at ordinary distances apart, the orchardist is almost certain to postpone thinning the trees until they have so badly crowded each other that their vitality is much impaired. Proper thinning requires the removal of 75% of the trees, and this is very hard to do as long as they are healthy and productive.

PLANTING TABLE.

Number of trees required per acre planted by square system:

10 ft. x 10 ft.	435	20 ft. x 20 ft.	108
10 ft. x 12 ft.	363	24 ft. x 24 ft.	75
10 ft. x 20 ft.	217	25 ft. x 25 ft.	70
12 ft. x 12 ft.	302	28 ft. x 28 ft.	55
12 ft. x 15 ft.	242	30 ft. x 30 ft.	50
15 ft. x 15 ft.	135	33 ft. x 33 ft.	40
16½ ft. x 16½ ft.	160	35 ft. x 35 ft.	35
18 ft. x 18 ft.	135	40 ft. x 40 ft.	27

LAYING OUT THE ORCHARD.

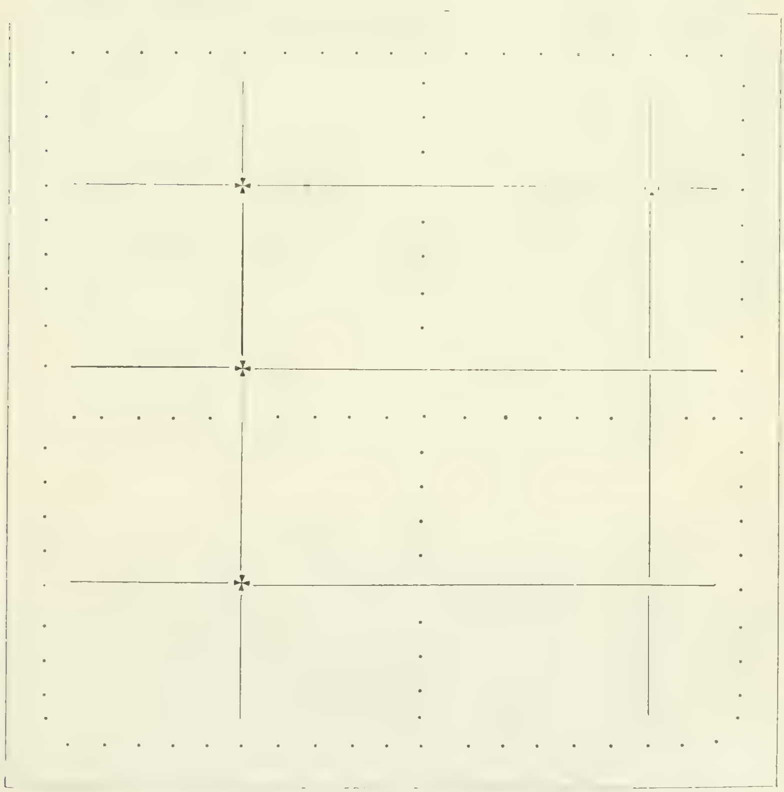
The problem of laying out the orchard is difficult, especially on rolling ground, and should be done carefully, so that the rows of trees may be straight. An orchard in which the rows are straight is much more attractive and satisfactory than one which appears to have been planted carelessly. The extra care and time devoted to aligning the rows of trees will be a source of much satisfaction during the whole life of the orchard.

The first thing to do is to establish a base line along one side of the field, preferably the longer side, and from this to extend all further operations. This should be established by a surveyor if possible, rather than to depend upon a fence line or road line, which are so often erroneous. If the field, to be set by the square or quincunx system, is not larger than 3 or 4 acres, and is comparatively level, another line should be run out at right angles to the base line, starting at the corner of the field where the first tree will stand. The direction of this line may be ascertained by placing a carpenter's square, or a mason's square upon 3 stakes, one of which is at the corner, another along the base line, and the third along the side line, so that one side of the square extends along the base line. Sighting along the other side of the square, one has the direction of the side line. Stout stakes should be set along this side at intervals corresponding to the distance the trees are to be set apart. Similarly, another line of strong stakes should be set along the opposite side of the field, and at right angles to the base line. From the corresponding stakes of these two side lines, a wire may be stretched tightly across the field, parallel to the base line, and this will indicate the location of the row of trees. Conspicuous tags should be fastened tightly along this wire at intervals equal to the distance apart the trees are

to be set in the row. A gardener's string would be just as good if it did not stretch in use, increasing the distance between the tags and causing the cross rows to be crooked. Then stakes should be set in the ground at the location of the tags.

When this is done the holes may be dug and the trees planted with the planting board.

If the field is a large one, a more extensive staking method must be employed. The following simple plan will be found very accurate where the work is carefully done. As indicated in the diagram below, a row of stakes is established entirely around the field, and near enough to the border of the field to avoid the location of any row of trees, the stakes being placed at intervals corresponding to the distance the trees are to be planted apart. These stakes should be painted or whitewashed at the top to make them conspicuous and easily seen at considerable distances. Then an intermediate row of stakes should be established across the field in each direction. These stakes being put exactly in line with the corresponding stakes on opposite sides of the field and again avoid the location of any row of trees. If the field is at all rolling, or if



for any reason the planters cannot see entirely across the field, more intermediate lines will be needed. None of these lines of stakes need

be exactly straight, but it is essential that the stakes be set perpendicular. With the stakes thus placed, the proper location of any tree in the field can be easily found, thus the hole-digger may use his shovel handle as a temporary stake and align it with two stakes in each of the two directions at right angles. The location of the handle indicates the center of the hole. In planting, the tree should be used as a temporary stake and aligned with two stakes in each of two directions at right angles. In this method any number of men may plant trees in the field at the same time, and the work may begin in any part of the field. When the planting is completed the stakes stand as a test of the thoroughness of the work done.

In the planning and planting of the hexagonal system, this plan may be used. As many stakes should be provided as there are trees to be planted. A wire should be prepared of the exact length that the trees are to be planted apart, and a ring or loop twisted in at each end by which the operator may hold it. After the base line is established, and stakes are planted along it just where each of the first row of trees will stand, one person (A) slips a finger through the ring at one end of the wire and another person (B) runs a small stick through the ring at the other end. (A) then puts his ring at the first stake in the base line, (B) steps to where he supposes the first tree of the second row will be and strikes a small segment of a circle upon the ground. Then (A) goes to the second stake in the first row and holds his end of the wire exactly to it. (B) describes another small segment of a circle from that stake, and where these two segments cross, a stake must be driven and this is the location of the first tree in the second row. Likewise these two operators may find the location of each tree in the second, third, fourth rows, etc., using each row in turn as a base line. Before doing any planting, the whole field should be measured and staked in the above way. If the work is done carefully the trees will be found to be in very straight rows in every way.

PLANTING THE TREE.

The ground should be smooth and in good tilth. Plowing along the line of tree rows may lessen the hand labor somewhat, and afford opportunity for surface drainage, but the holes must be dug by hand. The harder the ground, the wider and deeper the holes should be. In all cases they should be wide and deep enough to receive all the roots of the tree without it being necessary to crowd or twist them. If the bottom is hard, it should be picked until it is mellow, or some loose surface soil should be thrown in. Never throw coarse manure or sods into the bottom of the hole, hoping to furnish humus and fertility to the tree. While they are decomposing, they absorb moisture and cause heating, which is sure to injure the roots of the tree.

When the young tree is dug in the nursery, a portion of the root

system is removed, some roots are broken and the ends of others are ragged or torn. These broken roots and ragged ends should be cut off smoothly so that the cut surface will lie upon the bottom of the hole. Then if there is an abundance of fine roots, especially under the crown, they should be thinned out. If the trees are heeled-in in the fall, this root pruning may be done then and by spring the cut surface will have calloused over, though usually the roots are pruned just before planting.

If a stake has been placed to indicate the proper location of each tree, this location will be lost when the stake is pulled and the hole dug, unless a planting-board is used. This is a thin board 3 to 4 inches wide and 4 to 6 feet long, with a notch at its center and at each end. Before digging the hole, the planting-board should be placed on the ground with the notch in the center against the stake. (See Plate 1.) Then a stake should be driven in the ground fitting in the notch at each end. The board should then be lifted, laid aside and the hole dug, the board is then returned to its place and the tree stood in the notch, the exact original location of the stake. This is an accurate method of placing the tree, but many consider it too slow to be practical in large fields. In large fields the sighting method is usually to be preferred.

For convenience and rapidity, two men can work together in planting the trees. One man should stand the tree in its proper place in the hole and carefully spread out the roots in their natural direction. Then the second man should throw in some loose, moist surface soil, a little at a time, so that it thoroughly covers the roots on all sides, underneath, as well as above, and especially under the crown of the tree. After this has been done, and the ground is tramped firmly, the hole may be filled and be tramped more rapidly. Finally, the soil should be left mellow at the top, so that it will not bake and permit much moisture to escape. When the hole is filled, the tree should stand about two inches lower in the ground than it did in the nursery, except with dwarf pears, which should be set from three to six inches below the bud of graft.

In the case of fall planting, the ground should be mounded up about the trunk of the tree, and so provide ample surface drainage. Trees planted on locations exposed to strong prevailing winds should be leaned toward the wind slightly, or else be supported by a strong stake. This avoids lopsided rows so often seen on exposed slopes.

PRUNING THE YOUNG TREES.

Since some of the roots are removed when the tree is dug from the nursery, and possibly some are pruned off before planting, the tops must be cut back to produce a balanced condition. This should be done immediately after planting. The practice of doing this pruning before the tree is set is not often satisfactory. In doing the pruning, the orchardist should aim to top the trees low, from 18 to 24 inches above the ground. When the trees are full grown, pruning, spraying, thinning and harvesting will be more convenient than if headed high.

Apples, plums, pears and sour cherries should be pruned so as to leave

three to five main or scaffold limbs distributed up and down the trunk for from 12 to 15 inches to avoid bad crotches, and these should be as conveniently distributed as possible about the trunk so as not to make the tree lopsided or so that one limb will not grow above another and interfere with it. (Plate 2, Figs. 1 and 2.) These small branches should be cut back to from 2 to 6 buds, the cut being made just above a bud. Yearling peaches and sweet cherries should usually be pruned back to a whip. (Plate 2, Figs. 3 and 4.)

The pruning for the first four or five years should be very carefully and systematically done so that the young tree may produce a strong symmetrical open top. Each spring the main limbs should be cut back to make them grow stocky and strong. At the same time all undesirable branches should be cut out and the rest shaped so that the top will be open, admitting free circulation of air and sunlight.

Since different varieties of fruits have different natural habits of growth, these habits should be taken into consideration. Those naturally growing compact heads may be pruned so that the branches will grow outward while those with tops naturally open, need not be pruned so severely.

In all cases make smooth, clean cuts, and as close to the trunk limbs or buds as possible, but not so close as to injure the trunk or bud.

AFTER-CARE OF THE ORCHARD.

It is very essential that the young trees be kept in the best possible condition of thrift and health, hence it is necessary to conserve all the moisture and plant food in the soil. To do this, cultivate thoroughly, and systematically. Different soils and different conditions will alter the methods used. Early in the spring, as soon as the condition of the soil will permit, plow 6 or 8 inches deep. If the trees have been planted as deeply as they should be, this deep plowing will cause them to produce deep root systems not so apt to be injured by freezing or drouth. After this the soil should be frequently stirred to produce a shallow soil mulch and prevent baking or crusting of the surface and the consequent heavy loss of moisture by evaporation. The cultivation will also kill all weeds which are drains upon the soil moisture and available plant food. It also liberates the plant food and assists in decomposing any or all plant food that may be turned under.

About the first of August, cultivation should be stopped so that the trees will have an opportunity to mature and harden the season's growth and buds and prepare them for winter. At the last cultivation some plant, to serve as a cover crop, should be sown. This will absorb and conserve much available plant food that would otherwise be lost. It also prevents washing of the soil, holds the leaves and snow during the winter, and in the spring, when turned under, furnishes a considerable quantity of humus to the soil. If the soil is in need of nitrogen, such plants as clovers, vetches, peas, etc., should be used, otherwise, oats,

barley or buckwheat. If it is desirable, hoed crops, such as corn, potatoes or beans may be raised among the trees. The cultivation necessary for them will usually suffice for the trees. They should not be planted nearer than 3 or 4 feet from the ends of the branches, however, and greater care will need to be taken to maintain the fertility of the soil. Grain crops, such as wheat, rye or oats, should never be raised among the fruit trees, as they are heavy users of moisture and plant food. A clover sod may be grown between the rows, if sufficient space is left along the rows to cultivate. On the steep side of hills, or rocky fields, which should be avoided if possible, sod or straw mulches may be substituted for cultivation. Such a method, however, encourages surface root systems that are liable to injury in winter or drouths.

In cultivation, care should be taken to cover the ends of the whiffletrees with leather or rubber, and high hames or other projections on the harness should be discarded to avoid barking the trunks and limbs of the trees. A muzzle upon the horses's nose will avoid many nipped limbs.

In addition to the cultivation, the trees need to be fed to make them thrifty. There is nothing better for this than barnyard manure, if applied late in winter and also in the spring, so that the trees get the benefit early in the season. Two or three handfuls of nitrate of soda incorporated into the soil about the tree, but not in contact with the roots, several times in the season will be very beneficial. It is very quickly available and should be used with great care. Unleached hardwood ashes will furnish potash and lime that assist the tree in making a firm wood growth. Small quantities of phosphates will assist the trees in appropriating the other plant foods and help to mature the tree in the fall.

It is necessary, also, to keep the trees free from all injurious insects and diseases. Of the leaf-eating insects, there are the canker worms, cut worms, tent caterpillar, fall web worm, bud moth and tussock moth. These may be controlled by the use of some arsenical poison as arsenate of lead or Paris Green. Cut worms can usually be controlled by scattering two or three handfuls of a mixture of Paris Green and bran or Paris Green and finely cut clover leaves on the ground a few inches from the trunk of the young trees. Curl leaf on peaches and leaf diseases on apples, pears, cherries, etc., can be controlled by the use of Bordeaux mixture. Examination should frequently be made of the trunks to destroy all borers. San Jose scale may be controlled by spraying with the lime-sulphur wash.

Care should be taken to remove all weeds, grass or other litter which might harbor mice. It is also frequently advantageous to wrap the tree trunks with wire netting, tar paper, or thin boards to protect them from mice or rabbits.

If a peach, apricot or plum tree develops yellows or little peach, immediately remove and destroy it.

THE SELECTION OF VARIETIES.

One of the most important and difficult problems that the fruit grower has to solve, is the selection of varieties for his orchard. The choice of varieties should depend upon three principal considerations, the personal preferences of the grower, the purposes of the orchard and the locality. Failure to regard any one of these points will eventually bring failure to the orchard.

The personal preferences of the grower are of much more importance than is generally given them. A man will usually take greater care and pains with his orchard and make it more succcessful if it contains varieties which he likes best. This is especially so in the case of the small home orchard. There are a number of varieties which are considered valuable, high quality apples, but all have a few favorite varieties and if these are adaptable to the locality and to the purpose intended, they should be the varieties chosen.

The second consideration, the purpose of the orchard or the nature of the market to be supplied, is one which has been greatly underestimated in scores of Michigan orchards, and points to one primary reason why so many of them are so badly neglected and unprofitable. If the orchard is to be a home orchard, it should contain varieties affording a succession of fruits for as large a part of the year as possible. They should all be of high quality, part suitable for dessert and part suitable for cooking. Size, appearance and productivity may wisely be sacrificed to some extent, although these are exceedingly desirable qualities and contribute much to the satisfaction that the fruits should give.

The commercial orchardist must be governed in his choice of varieties by the demands of the market which he expects to supply. If his market is a local and select one, the orchard should contain varieties that afford a succession and are prolific bearers of good sized, good quality, and in most cases, attractive appearing fruit. The commercial orchardist, who purposes to dispose of his fruit in the general market, has a problem of his own. He must understand that markets differ largely in their requirements; as for instance, many eastern cities prefer white peaches, while Chicago prefers a yellow peach, Boston craves for Baldwins, New York wants Greenings, Chicago is a large consumer of Damson plums, Milwaukee covets prunes, etc. It must be acknowledged that many varieties which are not considered first-class and in some cases might be called inferior, can be disposed of to good advantage in almost all large general markets, because they are attractive to the eye on account of their size and color. This will always be true to a greater or less extent, still it is gratifying to realize that consumers are gradually cultivating their tastes for the better varieties even though they may lack slightly in size and may not be so attractive in color. While there will always be a market for varieties that are not considered standard, the market for the choicer varieties will surely increase and this is the market that will aways give the best returns.

Varieties differ so largely in adaptability to different climatic and soil conditions, that the grower must be exceedingly careful in his selection. Some varieties can endure greater extremes of cold than others, some require special soils. There are a few varieties that do comparatively well in almost all parts of the state, but most of the better varieties are more or less sensitive to their surroundings and it does not necessarily follow that, because a variety does well in one part of the state it will do equally well in others, even of the same latitude.

Many varieties which are successful in the western Michigan fruit belt, are absolute failures in other parts of the state. So the prospective orchardist must make a careful investigation to determine what varieties do best in his particular locality and conclude which of these will do best on his particular site and soil. Failure to do this means failure for the orchard.

The commercial orchardist should confine himself to a few varieties. Experience has proven time and again that it is much easier to dispose of the crop from an orchard if it has only a few varieties than if the orchard has only a few trees of several varieties. Only in exceptional cases, would it be wise to plant more than four or five varieties in a commercial orchard and many times fewer would be better. The grower can also make a more careful study of the special requirements of each variety and be able to produce them to better advantage.

Some varieties have delicate skins and bruise easily and hence are poor shippers. If the fruit must be shipped long distances to market, such varieties should not be included in a list for a commercial orchard. However, this will depend largely upon the care with which the fruit is handled in harvesting and marketing. Varieties for cold storage uses should be those which have good keeping qualities.

VARIETIES SUGGESTED.

Apples for Home Orchard—Yellow Transparent, Sweet Bough, Primate, Jeffries, Duchess of Oldenburg, Chenango, Dyer, Maiden Blush, Wealthy, Shiawassee, McIntosh, Fameuse, Jacobs Sweet, Sutton, Hubbardston, King, Wagener, Winter Banana, Grimes Golden, Tolman, Jonathan, Northern Spy, Rhode Island Greening, Red Canada, Golden Russett, Aiken.

Apples for Market—Yellow Transparent, Duchess of Oldenburg, Gravenstein, Wealthy, McIntosh, Fameuse, Hubbardston, King, Wagener, Grimes, Jonathan, Spy, Baldwin, Rhode Island Greening, Red Canada.

Crab-apples for Home Use—Martha, Transcendant and Dartmouth.

Crab-apples for Market—Hyslop.

Pears for Home Use—Summer Doyenne, Bloodgood, Clapp's Favorite, Bartlett, Manning Elizabeth, Seckel, Jones, Bosc, Sheldon, Anjou, Belle Lucrative, Duchess (Angouleme), Louise, Superfin, Dana's Hovey, Lawrence, Winter Nelis, Kieffer (for canning).

Pears for Market—Giffard, Bartlett, Seckel, Bosc, Clairgeau, Howell, Vermont Beauty, Anjou, Duchess (Angouleme), Kieffer.

Peaches for Home Use—Alexander, Dewey (or Wark), Early Michigan, Hale's Early, Crane's Yellow, Yellow St. John, Champion, Fitzgerald, Mountain Rose, Engle, New Prolific, Kalamazoo, Markham Chili, Gold Drop, Lemon Free, Banner, Salway.

Peaches for Market—Dewey or Wark, Early Michigan, Davidson, St. Johns, Early Crawford, Weed's Barnard, Engle's Mammoth, Kalamazoo, Crosby, New Prolific, Improved Chili, Elberta, Gold Drop, Lemon Free, Banner, Salway.

Plums for Home Use—Red June, Czar, Abundance, Jefferson, Bradshaw, Lombard, McLaughlin, French Damson, Fellenberg or Italian Prune, Monarch, Bavay's Green Gage (Reine Claude), Coe's Golden, Stanton.

Plums for Market—Japan: Red June, Burbank, October Purple. European: Bradshaw, Lombard, Black Diamond, Arch Duke, Pringle Damson, Shropshire, Grand Duke, Fellenberg, Monarch, Coe's Golden, Bavay, Copper.

Cherries for Home Use—Sour: Early Richmond, Montmorency. Sweet: Gov. Wood, May Duke, Tartarian, Yellow Spanish, Bing, Windsor.

Cherries for Market—Sour: Early Richmond, May Duke, Montmorency, Dukes, English Morello. Sweet: Gov. Wood, Napoleon, Yellow Spanish Tartarian, Bing, Windsor, Smith's Bigarreau.

Quinces—Orange, Rea Mammoth, Missouri Mammoth, Champion.

DESCRIPTION OF TREE AND FRUIT, OF PRINCIPAL VARIETIES SUGGESTED. IN ORDER OF HARVESTING:

Yellow Transparent—Tree of medium size, hardy, moderately vigorous, upright (compact), bears 4-6 years of age and prolifically. Should be thinned heavily to produce annual crops. Fruit—Season, late July and August; medium size, good quality, excellent for cooking, has tender yellow skin, bruises easily and cannot be shipped long distances.

Sweet Bough—Tree medium to large, hardy, vigorous, upright, spreading, bears early and prolifically, subject to canker. Fruit—Season, late July; large, excellent quality, good for dessert, cooking or local market, somewhat subject to scab.

Primate—Tree large, hardy, moderately vigorous, upright, spreading, bears 5-7 years of age, productive, somewhat subject to canker. Fruit—Season, ripens unevenly, August and September; medium to large, quality very good, juicy, excellent for dessert, somewhat subject to scab.

Oldenburg (Duchess of Oldenburg)—Tree medium size, vary hardy, moderately vigorous, bears at 4-6 years, yielding heavy crops biennially; sometimes subject to collar rot. Fruit—Season, ripens unevenly through late August and September, large size, excellent for cooking or market. Free from scab.

Maiden Blush—Tree medium size, hardy, vigorous, upright, spreading, bears early and usually every year. Fruit—Season, September and early

October; medium to large, attractive, good for dessert, cooking or market, has tender skin and must be handled carefully, very subject to scab.

Gravenstein—Tree large, hardy, vigorous, upright, spreading, bears moderately early and fairly well every second year, occasionally subject to canker. Fruit ripens unevenly, during late September until November, medium to large, good for cooking or market.

Wealthy—Tree medium size, hardy, moderately vigorous, upright, spreading, bears 4-6 years, very productive, requires heavy thinning. Fruit—ripens late September or early October, medium to large, good for dessert, cooking or market, very free from scab, drops badly.

McIntosh—Tree medium to large, hardy, vigorous, upright, spreading, bears 5-7 years and heavily every other year. Fruit ripens in October, medium to large in size, very attractive, excellent for dessert, cooking or market; flesh is tender and bruises easily and it cannnot be shipped long distances very subject to scab.

Fameuse (Snow)—Tree medium to large, hardy, vigorous, upright, spreading, bears 5-7 years, annually and prolifically. Fruit ripens in October, medium in size, attractive, extra for dessert, cooking or nearby market. Very subject to scab.

Hubbardston—Tree medium to large, fairly hardy, vigorous, upright, spreading, bears 5-6 years of age, very productive, requires heavy thinning. Sometimes subject to canker. Fruit ripens fore part of October, medium to very large, generally good for dessert, cooking or market until January. Smooth, very free from scab.

King—Tree large, vigorous, hardy, upright spreading, bears 6-8 years, generally not very productive, is subject to canker and collar rot. Fruit ripens fore part of October, large, attractive, extra fine for dessert, cooking and market, not very subject to scab, drops badly.

Wagener—Tree medium in size, hardy, moderately vigorous, upright spreading, bears 4-5 years, and so abundantly that it requires heavy thinning, especially while young to prevent stunting of tree. Fruit ripens in October, medium to large, attractive, excellent for dessert, cooking or market.

Grimes Golden—Tree medium to large, hardy, vigorous, upright spreading, bears 5-7 years, very productive, usually requires thinning to secure good size. Fruit ripens in fore part of October, excellent for dessert or cooking and sells well in markets where its quality is known. Somewhat subject to scab.

Jonathan—Tree medium to large, hardy, vigorous, upright spreading, bears 4-5 years, very productive and requires thinning. Should be planted on strong soil to get good sized fruit. Somewhat subject to collar rot. Fruit ripens in October, attractive, extra fine for dessert, culinary use or market. Very free from scab.

Northern Spy—Tree very large, should be planted 40-50 feet apart, very vigorous, upright, thick, spreading, seldom bears before 12 to 15 years of age, very productive as it grows older. Fruit ripens in October, large to very large, attractive, extra fine for dessert, culinary use or market. Quite subject to scab.

Baldwin—Tree large, hardy, vigorous, upright, spreading, seldom bears until 10-12 years of age, but then usually becomes very prolific bearer. Somewhat subject to canker. Fruit ripens about middle of

October, medium to large, attractive, excellent for dessert, culinary use and market.

Rhode Island Greening—Tree large, hardy vigorous, wide-spreading, drooping, dense, bears 8-10 years of age, and prolifically. Fruit ripens about middle of October, medium to very large, excellent for dessert, culinary use or market. Somewhat subject to scab.

Red Canada—Tree medium to large, lacks slightly in hardiness, vigorous, upright, dense, spreading, seldom bears before 10-12 years, often a shy bearer, seems to do especially well in southeastern counties of Michigan. Fruit ripens late October, medium to large, attractive, good for dessert, culinary or market use. Is an especially good keeper.

Winter Banana—Tree medium in size, hardy, vigorous, rather flat, spreading, bears 6-8 years and then is fairly productive. Fruit ripens early October, large to very large, attractive, much esteemed for dessert and culinary use, but shows bruises so badly that it is not prized highly as a commercial variety. Somewhat subject to scab.

Sutton (*Sutton's Beauty*)—Tree medium in size, hardy, vigorous, very upright, compact, bears 6-8 years, fairly productive. Fruit ripens middle of October, medium to large, very attractive, excellent for dessert, culinary or high class market. Somewhat subject to scab.

PEARS.

Giffard—Hardy and very productive, fruit medium size, juicy and melting, ripens middle of August, best of its season.

Bartlett—Tree large, hardy, vigorous, very productive, but very subject to "fire blight." Fruit large, tender, buttery, excellent for dessert, cooking or market. Ripens early September.

Seckel—Tree large, hardy, moderately vigorous, erect grower, very productive, very free from blight, requires high cultivation. Fruit small, fine-grained, very sweet, juicy and buttery. The standard of excellence among pears. Ripens late September or early October.

Bosc—Tree medium to large, hardy, vigorous and very productive, has crooked trunk and requires top working on some other stock. Flemish Beauty has proved very good. Fruit medium to large, russet, juicy, buttery, rich and sweet, excellent for dessert, cooking or market. Ripens October.

Duchess (*Angouleme*)—Tree medium to large, hardy, vigorous and very productive, does best when grown on quince stock. Fruit very large, melting, buttery, juicy, valuable for dessert, cooking or market. Ripens October.

Clairgeau—Tree medium, hardy, moderately vigorous, erect, moderately productive. Somewhat subject to blight. Fruit ripens large, somewhat granular, buttery, melting, often with rich flavor, but frequently poor, good for market. Ripens late October.

Howell—Tree medium size, hardy, vigorous, erect and very productive. Fruit medium to large, yellow, melting, buttery, moderately rich, usually good quality, good for dessert, cooking or market. Ripens late October.

Anjou—Tree large, very hardy, vigorous, upright spreading, very productive. Seldom bears before 10 years old. Fruit large, fine-grained, buttery, melting, with rich flavor, one of the most valuable dessert and market pears. Ripens, October.

Kieffer—Tree medium to large, very hardy, very vigorous, upright, dense, slightly spreading, usually very productive. In some places requires interplanting of some other variety. Bartlett or Lawrence are suggested. Fruit large to very large, poor quality, but a favorite of growers and canners. Ripens late October or early November.

PEACHES.

Dewey—Tree medium in size, hardy, vigorous, productive and requires heavy thinning. Fruit medium to large, yellow, nearly freestone, fair quality, ripens in August, good for early market. Somewhat subject to rot.

Wark—Tree medium in size, hardy, vigorous, productive. Fruit medium in size, yellow, clingstone, good quality, ripens in August. Good for early market.

Davidson—Tree medium in size, hardy, vigorous, very productive. Requires heavy thinning. Fruit medium to large, smooth skin, yellow, freestone, follows shortly after Dewey, good for dessert or market.

Early Michigan—Tree medium in size, hardy, vigorous, very productive. Requires careful thinning. Fruit medium to large, white, freestone, ripens about same time as Dewey, good for dessert or local market. Is very subject to rot.

St. Johns—Tree medium in size, somewhat tender in bud, vigorous, very productive in favorable years. Fruit medium to large, yellow, freestone, ripens about same time as Early Michigan, quality very good, good for dessert, culinary or market use, ripens about same time as Early Michigan.

Early Crawford—Tree large, tender in bud, very vigorous, requires severe heading in, fairly productive in favorable years. Fruit medium to large, yellow, freestone, good for dessert, culinary use or market. About two weeks later than St. Johns.

Engles Mammoth—Tree medium to large, hardy, very vigorous, productive. Fruit medium to large, attractive, yellow, freestone, valuable for dessert, culinary use or for market, ripens in September.

Kalamazoo—Tree large, hardy, very vigorous, productive. Fruit medium size, yellow, freestone, very good for dessert, culinary use or market, follows Engles very closely.

Crosby—Tree medium to large, hardy, vigorous, very productive, requires heavy thinning. Fruit inclined to be small unless thinned severely, yellow, freestone, very good for dessert, culinary or market use. Ripens about same time as Kalamazoo.

Elberta—Tree large, hardy, very vigorous, very productive. Fruit large, uniform in size and shape, yellow, highly colored, freestone, one of the most valuable market varieties, ripens shortly after Kalamazoo. Very subject to curl leaf.

New Prolific—Tree large, hardy, vigorous and very productive. Fruit large, yellow, smooth, freestone, valuable for dessert, culinary or market. Ripens with Elberta.

Gold Drop—Tree medium in size, hardy, vigorous, and very productive. Requires severe thinning to secure size in fruit. Fruit small to medium, yellow, freestone, unsurpassed for dessert or culinary use, but

most too small for good market variety. Drops badly and is subject to scab.

Lemon Free—Tree medium size, moderately vigorous, hardy, very productive. Fruit medium to large, yellow, freestone, good variety for dessert, culinary or late market, ripens October, too late for northern counties.

Banner—Tree medium in size, hardy, vigorous, productive, requires thinning. Fruit has tendency to run small, yellow, freestone, good for dessert, culinary or market use, ripens with Lemon Free, too late for northern counties. Drops badly.

Salway—Tree large, hardy, vigorous, productive. Fruit medium, yellow, freestone, good for dessert, culinary or late market in southern counties. Very subject to scab.

PLUMS.

Red June—Tree medium size, upright, moderately vigorous, fairly hardy, productive. Fruit medium, red, firm flesh, good for dessert or early market use. Ripens early in August.

Burbank—Tree large, flat spreading, vigorous, hardy, very productive. Fruit medium to very large, dark red, or purplish, firm juicy flesh, fair for dessert or culinary purposes and sell well in some markets. Ripens last party of August and early September. Very subject to brown rot.

October Purple—Tree large, upright, spreading, hardy, very vigorous, very productive. Fruit medium to large, reddish-purple, firm, juicy, ripens about October 1st, good for late market.

Bradshaw—Tree large, upright, spreading, hardy, very vigorous, very productive. Fruit large, purple, firm, juicy, good for dessert, culinary or market use, ripens in August.

Lombard—Tree large, upright, spreading, hardy, vigorous, very productive, does well in all parts of Michigan. Fruit medium size, violet red, juicy, highly prized for home use and valuable for local market, ripens early in September. Very subject to rot.

Black Diamond—Tree large, upright, spreading, hardy, vigorous, very productive. Fruit large, blue, firm, *excellent* for market purposes, ripens early in September.

Arch Duke—Tree large, spreading, dense, fairly hardy, vigorous and productive. Fruit large blue, freestone, firm flesh, good for market, ripens fore part of September, drops badly.

Shropshire Damson—Tree medium in size, upright, dense, hardy, vigorous, productive every second year. Fruit small, blue, firm, good for culinary and market use, ripens about middle of September.

Grand Duke—Tree medium to large, upright, spreading, moderately hardy, vigorous, very productive. Fruit large, blue, firm flesh, good for late market, ripens last of September, rots very badly under favorable conditions.

Fellenberg—Tree medium in size, flat, spreading, hardy, vigorous, productive. Fruit medium size, blue, firm flesh, freestone, excellent for dessert, culinary or market use, very subject to attacks of curculio, ripens middle to latter part of September.

Monarch—Tree large, upright, spreading, moderately hardy, vigorous,

very productive. Fruit medium to large, blue, firm, freestone, excellent for dessert, culinary or market use, ripens late October. Somewhat subject to rot.

Coes Golden—Tree above medium to large, flat, spreading, moderately hardy, vigorous, productive. Fruit large, yellow, firm, juicy, sweet, excellent for dessert or culinary use, and sells well where known, ripens late September or early October.

Bovay—Tree medium size, upright, spreading to roundish, rather tender, moderately vigorous, very productive. Fruit medium size, greenish-yellow, firm, juicy, sweet, excellent for dessert and especially for culinary purposes, ripens late September or early October.

Copper—Tree medium upright, slightly spreading, hardy, moderately vigorous, productive. Fruit small, purple, firm, juicy, good for very late market, ripens middle of October or later.

SOUR CHERRIES.

Early Richmond—Tree medium size, spreading, hardy, vigorous, regular and prolific bearer. Fruit medium size, bright red, juicy, best early sour cherry for culinary or market use, ripens from middle of June until in July.

May Duke—Tree medium size, spreading, hardy, vigorous, productive. Fruit large, dark red, juicy, rich subacid, valuable for culinary or market use, ripens late June or early July.

Montmorency—Tree large, spreading, hardy, very vigorous, regular and profuse bearer. Fruit large, crimson red, juicy, most valuable sour cherry for market or culinary use, ripens July.

English Morello—Tree medium size, low spreading, hardy, moderately vigorous, prolific bearer, very subject to cherry leaf spot disease. Fruit large, very dark red to black, juicy, very sour, valuable late variety, ripens last of July and early August.

SWEET CHERRIES.

Gov. Wood—Tree large, upright, spreading, hardy, vigorous and very productive. Fruit large, light yellow, tender, juicy, good for dessert or canning, but does not ship well. Somewhat subject to rot. Ripens irregularly latter part of June to early July.

Napoleon—Tree large, spreading, hardy, vigorous and very productive. Fruit large, pale yellow, firm, juicy, sweet, good for dessert or canning purposes or local market, shows bruises too badly to ship well, ripens in July.

Black Tartarian—Tree medium, upright, slightly spreading, hardy, vigorous, very productive. Fruit large, black, tender, juicy, mild, sweet, one of the most valuable varieties for dessert, culinary or market use, ripens early to latter part of July.

Yellow Spanish—Tree medium to large, spreading, hardy, vigorous, productive. Fruit large, pale yellow, firm, juicy, good for dessert or canning purposes or local market, ripens latter part of June to early July.

Bing—Tree medium to large, upright, spreading, hardy, vigorous, very productive. Fruit very large, black, firm, juicy, very valuable for dessert, culinary or market purposes, ripens about middle of July. Very subject to rot.

Smith's Bigarreau—Tree very large, upright, spreading, very hardy and vigorous, moderately productive. Fruit very large, black, firm, juicy, very choice for dessert, culinary or market uses, ripens latter part of July. Somewhat subject to rot.

Windsor—Tree very large, upright, spreading, hardy, vigorous, is difficult to get started, very productive. Fruit large, black, firm, juicy, valuable variety for dessert, culinary or market purposes, ripens latter part of July. Very subject to rot.

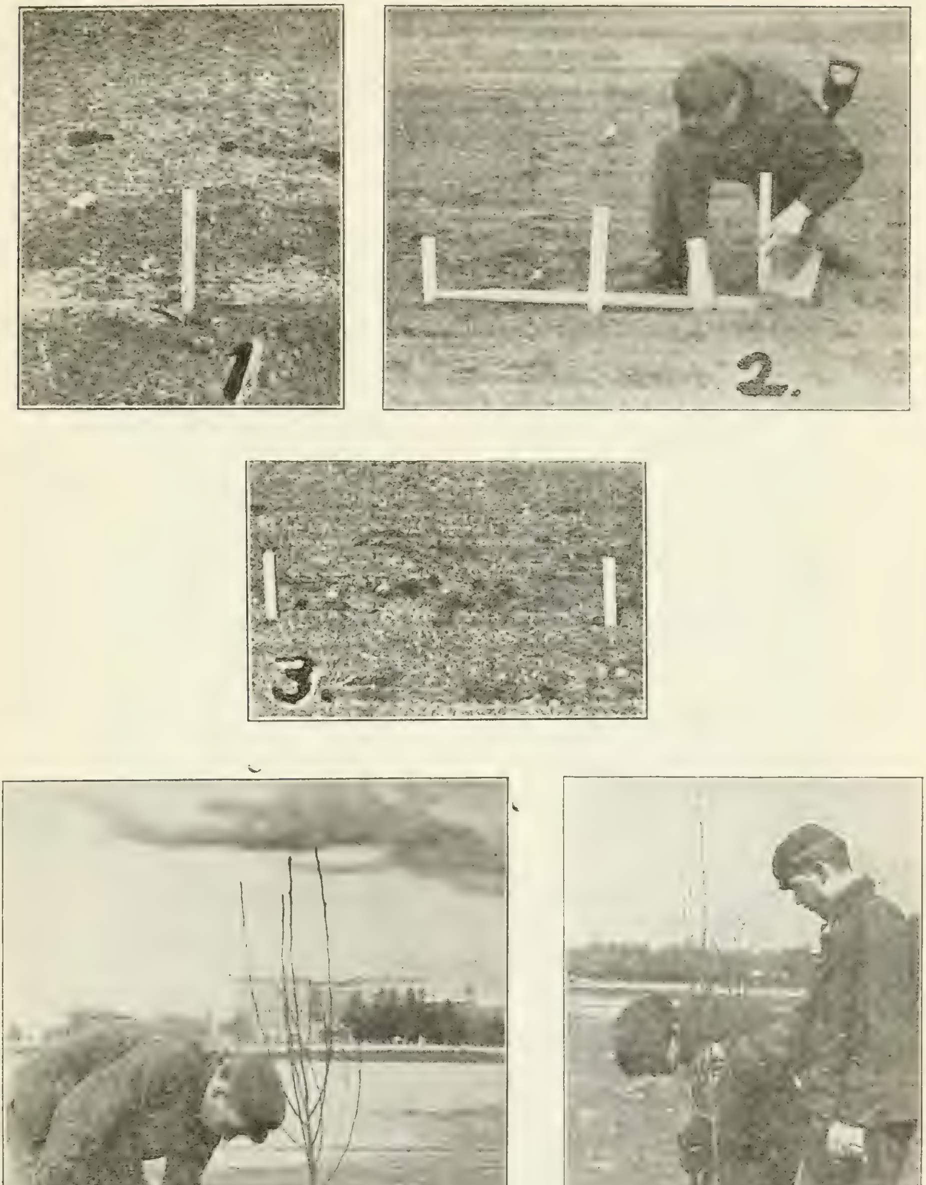


PLATE I. PLANTING A TREE. 1. Stake where tree is to stand. 2. Planting board in use. 3. Ready to dig hole. 4. Planting the tree, spreading the roots. 5. Tramping the soil firmly about the tree.

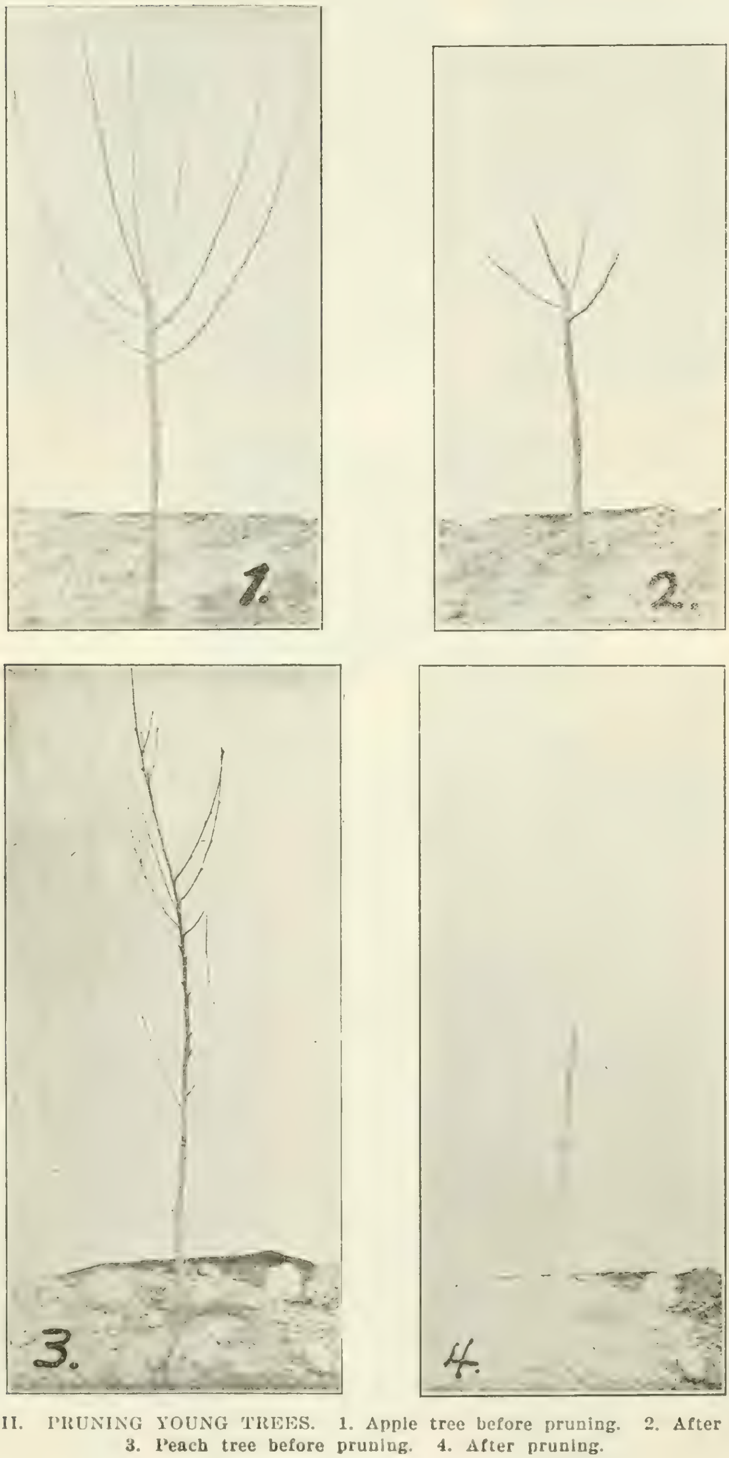


PLATE II. PRUNING YOUNG TREES. 1. Apple tree before pruning. 2. After pruning
3. Peach tree before pruning. 4. After pruning.

FERTILIZER ANALYSES.

Bulletin No. 263.

ANDREW J. PATTEN, O. B. WINTER AND C. G. CLIPPERT.

SUMMARY OF FERTILIZER LAW.

The inspection and analyses of the commercial fertilizers offered for sale in Michigan are made under authority of an act of the Legislature, approved March 10, 1885. The full text of the law has been printed in former bulletins, and its salient points alone will be referred to here. It provides that all commercial fertilizers, retailing for more than ten dollars per ton, shall be accompanied by a statement certifying the number of net pounds in the given sack, the brand, name and address of the manufacturer, and a chemical analysis stating the percentages of nitrogen, of potash soluble in water, of available (soluble and reverted) phosphoric acid, and the insoluble phosphoric acid. (Sec. 1.) It provides that the manufacturer, importer or agent (the latter only in case the manufacturer fails to comply with the law), shall pay annually a license fee of twenty dollars for each brand offered for sale. (Sec. 3.) It provides that any person offering unguaranteed or over-guaranteed goods, shall be subject to a fine. (Sec. 6.) The full text will be furnished on application.

LICENSED BRANDS.

Twenty-four manufacturers and fertilizer companies have licensed 208 distinct brands for sale in the state during the season of 1910. These brands, appearing in the following tables of analyses, and no others can be legally sold.

Parties manufacturing or importing fertilizers for their own use and not for sale are not affected by the restrictions of the law.

COLLECTION OF SAMPLES.

The sampling agents of the Station, during the months of April, May and June, drew 404 samples from dealers' stocks representing 181 different brands. The failure to get samples of 27 brands is due to the fact that many of them are sold only in the fall, then, too, a few companies sell direct to the consumer through the Grange and other organizations and consequently it is only by chance that samples of such goods are obtained. If persons ordering goods in this way wish to have them inspected they will protect themselves and at the same time confer a favor on this department by notifying us, and upon the arrival of the goods an inspector will be sent to draw samples.

It is the desire of this department to make the inspection as complete as possible, and any information to further this end from dealer or consumer will be greatly appreciated. In all cases of failure to find a brand on the market, the analysis was made on the manufacturer's sample as indicated in the tables of analyses.

RESULTS OF INSPECTION.

A study of the tables of analyses shows that, of the 234 samples analyzed, representing 208 brands, 54 (23%) are below guarantee* in one or more constituents. Twenty-six (11%) are below guarantee in nitrogen, 5 (2.1%) are below guarantee in available phosphoric acid, 2 (0.9%) are below guarantee in total phosphoric acid and 26 (11%) are below guarantee in potash. Three (1.3%) are below guarantee in nitrogen and potash, 2 (0.9%) in nitrogen and available phosphoric acid.

While there are, as stated above, 54 samples falling below guarantee in one or more constituents, there are, however, only 10 (4.3%) that are more, than 75 cents per ton below their guaranteed commercial value. That is, the shortage in one constituent is compensated by an excess of the guarantees in the other constituents. This is a very satisfactory showing.

SCHEDULE OF TRADE VALUES.

In accordance with the custom adopted and followed in previous years, the following schedule of prices for determining the commercial valuation of a fertilizer is published:

Nitrogen	18½c.	per	pound
Potash soluble in water	4.8c.	"	"
Available phosphoric acid	5c.	"	"
Total phosphoric acid in bone	4c.	"	"
Insoluble phosphoric acid in fertilizers containing nitrogen	2c.	"	"

In fertilizers containing no nitrogen no value is given to insoluble phosphoric acid. The valuation of a fertilizer is determined as follows: The percentage or pounds per hundred of each ingredient (nitrogen, available phosphoric acid, insoluble phosphoric acid and potash) is multiplied by 20, giving the number of pounds of each ingredient in a ton. These figures are then multiplied by their respective pound prices.

In the last column of the table of analyses headed "Valuation" is given the commercial valuation of the samples as guaranteed and as found based upon the prices quoted above.

COMMERCIAL VALUATIONS.

In calculating the valuations we have assumed that the sources of the various ingredients have been the same in all cases, which of course is not true and also unfair to the manufacturer using only high grade goods, as it places the manufacturer who uses low grade materials on the same level.

*A shortage of more than 0.10 per cent of nitrogen or more than 0.20 per cent of available phosphoric or potash is considered below guarantee.

However, it should be clearly understood that a station valuation does not represent the proper retail price of the fertilizer at the point of consumption. It does represent the cash cost, at the larger fertilizer centers of the middle west, of an amount of nitrogen, available phosphoric acid and potash in unmixed, standard raw materials of good quality, corresponding with the same amount found in one ton of the fertilizer in question.

The difference between the selling price and valuation is represented by the cost of storing, grinding, bagging, hauling and freighting the goods, commissions to agents and dealers, bad debts, depreciation of machinery, interest on investment, etc. The percentage of difference between the valuation and selling price should not be more than 35 or 40.

Commercial valuations are useful to show whether a fertilizer is worth its guaranteed money value. Purchasers will often find them useful in comparing the relative values of similar brands offered by different manufacturers.

The commercial valuation bears no relation to the agricultural value of a fertilizer, this is measured only by the increased yield of crop due to its use.

The mixing of the ingredients of which a fertilizer is composed does not increase their crop-producing power, they would produce the same effect if applied separately. The mixing simply lessens the labor of applying the materials.

Following are the names of parties from whose stocks samples were drawn:

Adair—C. H. Lipke.
Adrian—Cutler, Dickerson & Co., W. R. Bradish, C. C. Van Doren.
Almont—Frank Bishop, J. Eastman.
Armada—Bailey & Ruby.
Azalia—Calvin Critchett, Fred Banchman.
Battle Creek—Robert Binder, J. E. Moon.
Bay City—Goodeyne & Shindler.
Benton Harbor—B. M. Nowlen & Co., C. E. & C. H. Hilton.
Blissfield—Continental Sugar Co., M Wolverton, W. A. Wortley.
Brown City—John H. Linck, J. C. Dean.
Capac—Lang Bros.
Carlton—L. J. Guermann, C. H. Reiser, Geo. Hoerl, B. Moore, Elmer Hoyt, Gorden Wager.
Charlotte—Colburn & Fulton Lumber Co.
Clayton—E. H. Hutchins.
Coloma—J. T. Vanderveer, Wm. Stratton, Rube Hazen.
Coopersville—Lang Bros., Reynolds Bros.
Covert—J. R. Speilman & Co.
Croswell—Sandusky Grain Co.
Davison—Burroughs & Wolohan Elec. Co., Downer & Fairchilds, R. E. Moss, J. F. Cortright.
Deerfield—Frank Timmins.
Disco—J. W. Switzer.
Detroit—The Lohrman Seed Co.
Dryden—Frank Bartlett.
Dundee—W. R. Haines, S. H. Reynolds.

East Lansing—C. D. Woodbury.
Erie—Choate & Benore.
Flint—Burroughs & Son.
Fremont—Dirk Kolk.
Grand Haven—Speidel & Swartz.
Grape—Elmer Smock.
Grand Rapids—Jones Seed Co., Brown Seed Co., Eagle Hide Co.
Hillsdale—G. A. Aldrich & Son, C. H. Burlingame & Co.
Holland—Mulder & Lugas, Klaas Dykhuis, H. H. Zwemer, John Meeswesner, Albert Alferink, Henry Siersma, Geo. A. Cook & Co.
Hudson—W. H. Rhead, J. A. Dillon, Jr.
Ida—S. A. Kring, N. A. Weipert, John Nichols.
Imlay City—F. Fairweather, G. W. Quirk, J. W. Taylor, Walter Walker.
Inkster—Geo. C. Walker.
Jackson—Isbell Seed Co., James Boland Fert. Co.
Kalamazoo—Woodham, Oakley & Oldfield Co., Walter T. Vetterlein, Mershon & Bartlett Co., Miller, Rider & Winterburn.
Lansing—DuBois & Hughes, The Briggs Co., Lansing Artificial Stone Co.
Lawton—Michigan Fruit Exchange.
Lapeer—Lapeer Elevator Co., R. King.
Lenox—Ira Lovejoy, Farmers' Elevator Co., Gilbert & Newberry.
Manchester—Adam G. Houch, Lanier & Hoffer.
Marine City—Joseph Babel, John Schnell, Zimmerman Bros., Joe Hacker.
Mason—Eli Han.
Maybee—M. L. Blanch, Henry Kohler, Garmlich & Maybee.
Memphis—Day & McCall.
Milan—F. G. Hasley & Co., T. W. Tolladay, F. S. Olds.
Mt. Clemens—John N. Tucker.
Muskegon—John Stegink, J. E. Marvin, Joe Leng.
New Boston—R. E. Krause.
New Buffalo—Seigmund Bros.
Niles—J. S. Tuttle.
Nunica—E. W. Hass, J. D. Pickett.
Otter Lake—Stockbridge Elevator Co.
Owosso—A. B. Cook.
Paw Paw—G. S. Woodworth, Michigan Fruit Exchange.
Petersburg—C. J. Cilley, Geo. C. Cox, H. S. Logan & Son, Chas. Van Vleet, Chas. Wadsworth, E. Thompson.
Portland—H. O. Beebe.
Reading—W. M. Cahou, Rigelman Bros., E. Davie, Kellog & Young.
Redford—C. A. Lasher, Hugh Houk.
Rochester—Chas. Burr.
Rollin—L. C. Fitts.
Romeo—Bradley & Chubb.
Royal Oak—P. Backer, J. M. Lawson.
Saginaw—The Henry W. Carr Co.
St. Clair—Matt Stine, Ricor & Smith, Geo. C. Solis.
St. Joseph—E. Burton.

Sebewaing—G. Gettel.
Smiths Creek—Louie Brill.
South Haven—Orlo Westgate.
Steamburg—W. L. Kelley.
Strasburg—C. W. Rau, J. F. Meyer.
Tecumseh—Slayton & Son.
Temperance—J. W. Kinney, A. J. Brunt & Son.
Three Oaks—Chas. F. Bachman.
Ulby—F. A. Brown, Thos. Richardson.
Vriesland—T. W. Haitsma.
Waldenburg—Louis Stine & Son.
Waltz—Robert Waltz, Ludwig Krzszke.
Warren—F. A. Reddick.
Washington—John Dernberger, R. A. Teeter.
Wayne—J. H. Lang, N. T. Johnson, Chas. Goudy.
Willis—Geo. Freeman, R. J. M. King.
Willow—Jesse Butler.
Yagerville—C. H. Scheurer.
Ypsilanti—M. Dawson, O. E. Thompson & Son.
Zeeland—Isaac Van Dyke, Henry Scholten, G. W. Hungerink, B. Van Raalte, Zeeland Milling Co., G. W. Scholten.

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Agricultural Chemical Co., Detroit, Mich.		
2423	Banner Dissolved Bone	Detroit	Claimed Found
2448	Beet Fertilizer	Holland	Claimed Found
2424	Fine Ground Bone	Ypsilanti	Claimed Found
2310	High Grade Bone and Potash	Adrian	Claimed Found
2399	High Grade Garden and Vegetable Fertilizer	Milan	Claimed Found
2311	Maine Potato Formula	Blissfield	Claimed Found
2400	M, and I. Special Manure	Azalia	Claimed Found
2312	Michigan 10 per cent Potash Manure	Yagerville	Claimed Found
2401	New York State Special	Willis	Claimed Found
2425	Muriate of Potash	Mason	Claimed Found
2426	Nitrate of Soda	Mason	Claimed Found
2546	Bradley's Acid Phosphate	Manufacture's sample	Claimed Found
2520	Bradley's Alkaline Bone and Potash	Manufacturer's sample	Claimed Found
2427	Bradley's B. D. Sea Fowl Guano	Waldenburg	Claimed Found

1910, expressed in parts in one hundred.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
....	.... 37.25	.... 0.47	34 36.78	....	$34 00 36 78
1.23 1.28	11 11.20	.... 0.87	9 10.33	2 **1.73**	16 25 17 05
2.47 2.48	20 25.85	....	....	....	25 09 29 82
....	12 13.51	.... 2.31	10 11.20	5 5.74	14 80 16 71
1.65 1.71	10 10.47	.... 0.98	8 9.49	5 4.90	19 67 20 88
1.65 1.89	10 10.59	.... 0.72	8 9.87	10 10.02	24 47 26 74
2.47 2.45	10 10.07	.... 0.92	8 9.15	6 6.31	24 65 24 60
0.82 0.98	7 7.31	.... 0.46	5 6.85	10 10.77	18 42 20 98
0.82 0.99	10 10.47	.... 0.73	8 9.74	3 2.97	14 70 16 52
....	....	....	....	49 53.05	47 04 50 93
15 15.73	....	....	....	....	55 20 57 90
....	12 14.30	.... 2.24	10 12.06	....	10 00 12 06
....	12 13.07	.... 1.28	10 11.79	2 **1.74**	11 92 13 47
2.06 2.07	10 10.95	.... 1.06	8 9.89	1.50 1.53	17 82 19 40

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Agricultural Chemical Co.—*Con.*		
2313	Bradley's Dissolved Bone with Potash	Yagerville	Claimed Found
2397	Bradley's Niagara Phosphate	Milan	Claimed Found
2450	Bradley's Soluble Dissolved Bone	Grand Rapids	Claimed Found
2398	Bradley's Special Potash Fertilizer	Ypsilanti	Claimed Found
2428	Crocker's Ammoniated Wheat and Corn Phosphate	Mason	Claimed Found
2465	Crocker's Dissolved Bone and Potash	Memphis	Claimed Found
2568	Crocker's Dissolved Bone and Potash	Lapeer	Claimed Found
2429	Crocker's General Crop Phosphate	Mason	Claimed Found
2314	Crocker's New Rival Ammoniated Superphosphate	Erie	Claimed Found
2549	Crocker's New Rival Ammoniated Superphosphate	Lapeer	Claimed Found
2315	Crocker's Universal Grain Grower	Erie	Claimed Found
2316	A-1 Potash Fertilizer	Waltz	Claimed Found
2564	A-1 Potash Fertilizer	Strasburg	Claimed Found
2494	High Potash Phosphate	Ubly	Claimed Found
2321	Red Line Complete Manure	Carlton	Claimed Found

1910, expressed in parts in one hundred.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
1.03 1.16	10 10.48	.... 0.76	8 9.72	2 2.26	$14 51 16 46
0.82 0.96	9 9.32	.... 0.93	7 8.39	1 0.95	11 78 13 19
....	16 18.02	.... 1.82	14 16.20	....	14 00 16 20
0.82 0.91	10 10.00	.... 0.70	8 9.30	3 3.04	14 70 15 85
2.06 2.15	10 11.00	.... 1.24	8 9.76	1.50 1.85	17 82 19 96
....	12 13.30	.... 1.86	10 11.44	2 **1.75**	11 92 13 12
....	12 13.45	.... 1.53	10 11.92	2 1.82	11 92 13 67
0.82 0.96	9 9.47	.... 1.34	7 8.13	1 0.92	11 78 13 08
1.23 1.32	11 11.49	.... 0.88	9 10.61	2 1.84	16 25 17 59
1.23 1.31	11 12.22	.... 1.19	9 11.03	2 1.83	16 25 18 09
0.82 0.97	10 10.93	.... 1.13	8 9.80	2 1.93	13 74 15 67
0.82 0.84	10 10.68	.... 1.00	8 9.68	3 **2.79**	14 70 15 85
0.82 0.89	10 10.17	.... 0.53	8 9.64	3 2.83	14 70 15 84
....	12 13.97	.... 2.16	10 11.81	5 **4.68**	14 80 16 30
0.82 0.83	9 9.67	.... 0.44	7 9.23	1 1.13	11 78 13 55

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Agricultural Chemical Co.—*Con.*		
2508	Red Line Phosphate	East Lansing	Claimed Found
2452	Red Line Phosphate with Potash	Muskegon	Claimed Found
2567	Red Line Phosphate with Potash	Davison	Claimed Found
2402	Wolverine Phosphate	Maybee	Claimed Found
2430	Homestead Best Potato Fertilizer	Ypsilanti	Claimed Found
2570	Homestead Best Potato Fertilizer	Muskegon	Claimed Found
2317	Homestead Bone Black Fertilizer	Waltz	Claimed Found
2318	Homestead High Grade Garden and Vegetable Fertilizer	Carlton	Claimed Found
2319	Homestead Special Beet Fertilizer	Petersburg	Claimed Found
2451	Homestead Sugar Beet Fertilizer	Vriesland	Claimed Found
2320	Homestead 10 per cent Potash Manure	Petersburg	Claimed Found
2453	Niagara Dissolved Bone and Potash	Adair	Claimed Found
2386	Niagara Grain and Grass Grower	Wayne	Claimed Found
2322	Niagara Potato and Vegetable Fertilizer	Adrian	Claimed Found

1910, expressed in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
....	16 19.05	.... 1.96	14 17.09	....	$14 00 17 09
....	12 13.37	.... 1.56	10 11.81	2 **1.69**	11 92 13 43
....	12 13.45	.... 1.41	10 12.04	2 **1.63**	11 92 14 61
....	12 13.14	.... 1.84	10 11.30	....	10 00 11 30
1.65 1.76	10 10.32	.... 1.16	8 9.16	10 **9.52**	24 47 25 25
1.65 1.65	10 10.45	.... 0.62	8 9.83	10 10.03	24 47 25 78
2.06 2.26	10 10.85	.... 0.99	8 9.86	1.50 1.56	17 82 20 08
1.65 1.68	10 11.46	.... 2.07	8 9.39	5 5.00	19 67 21 20
1.65 1.83	10 10.44	.... 0.84	8 9.60	5 4.93	19 80 21 41
1.23 1.40	11 11.60	.... 0.77	9 10.83	2 **1.80**	16 25 18 02
0.82 1.06	7 7.51	.... 0.46	5 7.05	10 10.87	18 42 21 41
....	12 13.62	.... 2.05	10 11.57	2 **1.71**	11 92 13 21
0.82 0.84	9 9.42	.... 1.64	7 7.78	1 1.06	11 78 12 55
2.06 2.34	10 10.17	.... 0.89	8 9.28	3 3.49	19 26 21 61

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Agricultural Chemical Co.—*Con.*		
2323	Niagara Wheat and Corn Producer	Adrian	Claimed.... Found.....
2521	Horse Shoe Acidulated Bone and Potash	Manufacturer's sample	Claimed.... Found.....
2324	Horse Shoe Animal Bone Manure	Blissfield	Claimed.... Found.....
2325	Horse Shoe Corn and Wheat Grower	Blissfield	Claimed.... Found.....
2326	Horse Shoe Garden City Superphosphate	Blissfield	Claimed.... Found.....
2327	Horse Shoe High Grade Vegetable Fertilizer	Adrian	Claimed.... Found.....
2328	Horse Shoe Potash Manure	Blissfield	Claimed.... Found.....
2495	Horse Shoe Quick Acting Phosphate	Ubly	Claimed.... Found.....
2522	Horse Shoe Special Onion and Vegetable Manure	Manufacturer's sample	Claimed.... Found.....
2403	Horse Shoe Sugar Beet Fertilizer	Dundee	Claimed.... Found.....
2496	Horse Shoe 10–5 Potash Manure	Brown City	Claimed.... Found.....
2329	Horse Shoe 3–8–6 Fertilizer	Blissfield	Claimed.... Found.....
2330	Boar's Head Corn and Wheat Grower	Temperance	Claimed.... Found.....
2331	Boar's Head Faultless Grain Grower	Temperance	Claimed.... Found.....

1910, expressed in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
1.23 1.34	11 11.72	.... 0.30	9 11.42	2 2.21	$16 25 18 61
0.82 1.04	12 13.40	.... 1.31	10 12.09	1 1.08	14 78 17 48
0.82 1.06	9 10.36	.... 0.48	7 9.88	1 1.83	11 78 15 73
1.65 1.66	10 11.25	.... 0.76	8 10.49	2 2.12	16 79 18 94
2.06 2.38	10 10.67	.... 0.57	8 10.10	1.50 1.69	17 82 20 72
1.65 1.75	10 10.90	.... 0.80	8 10.10	5 4.98	19 67 21 64
0.82 0.84	10 10.32	.... 0.67	8 9.65	3 3.14	14 70 16 04
....	12 13.85	.... 1.83	10 12.02	....	10 00 12 02
0.82 0.83	7 6.75	.... 0.58	5 6.17	10 9.73	18 42 18 81
1.23 1.33	11 10.71	.... 1.25	9 9.46	2 1.95	16 25 16 73
....	12 14.00	.... 2.14	10 11.86	5 6.07	14 80 17 69
2.47 2.68	10 10.42	.... 0.69	8 9.73	6 5.90	23 65 25 55
1.65 1.88	10 10.72	.... 0.54	8 10.18	2 2.00	16 79 19 04
0.82 0.83	9 9.57	.... 0.70	7 8.87	1 1.29	11 78 13 45

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Agricultural Chemical Co.—*Con.*		
2332	Boar's Head High Grade Vegetable Fertilizer.......	Temperance..........	Claimed.... Found.....
2404	Boar's Head Potash Phosphate Fertilizer...........	Azalia...............	Claimed.... Found.....
2454	Boar's Head Soluble Phosphate....................	Holland..............	Claimed.... Found.....
2523	Boar's Head Sugar Beet Grower..................	Manufacturer's sample..	Claimed.... Found.....
2333	Boar's Head Sure Growth Potash Manure..........	Temperance..........	Claimed.... Found.....
2334	Boar's Head 10% Potash Composition.............	Temperance..........	Claimed.... Found.....
	The American Fertilizer Co., Chicago, Ill.		
2392	Union Brand Complete Crop Grower..............	Tecumseh............	Claimed.... Found.....
2385	Union Brand Corn and General Crop Grower........	Hudson..............	Claimed.... Found.....
2393	Union Brand Gardner's Favorite..................	Tecumseh............	Claimed.... Found.....
2431	Union Brand General Cropper.....................	Ypsilanti............	Claimed.... Found.....
2394	Union Brand High Grade Phosphate and Potash....	Tecumseh............	Claimed.... Found.....
2525	Union Brand High Grade Acid Phosphate..........	Manufacturer's sample.	Claimed.... Found.....
2524	Union Brand High Grade Celery and General Trucker	Manufacturer's sample.	Claimed.... Found.....
2432	Union Brand High Grade Sugar Beet Grower.......	Strasburg............	Claimed.... Found.....

1910, expressd in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
1.65 1.76	10 10.55	.... 0.93	8 9.62	5 5.02	$19 67 21 29
....	12 12.65	.... 1.80	10 10.85	5 4.87	14 80 15 52
....	12 13.75	.... 2.12	10 11.63	....	10 00 11 63
1.23 1.21	11 11.75	.... 0.96	9 10.79	2 2.06	16 25 17 61
0.82 0.86	10 10.55	.... 0.64	8 9.91	3 3.37	14 70 16 57
0.82 0.92	7 7.30	.... 0.41	5 6.89	10 10.37	18 42 20 38
1.65 1.73	.... 9.40	1.50 0.58	8 8.82	2 2.33	16 59 17 66
0.82 0.84	.... 11.12	1 0.92	8 10.20	4 3.94	15 26 17 44
3.30 3.21	.... 10.46	2 0.27	9 10.19	10 11.75	31 54 33 41
0.82 1.07	.... 11.15	1 1.62	8 9.53	1 0.93	12 38 15 01
....	.... 12.27	1 0.78	10 11.49	2 2.47	11 92 13 86
....	.... 1.700	1 0.74	14 16.26	....	14 00 16 26
0.82 1.24	.... 8.35	1 0.74	6 7.61	10 10.86	19 02 22 90
2.50 **1.83**	.... 10.57	2 2.26	8 8.31	5 6.06	22 80 **21 77**

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	American Agricultural Chemical Co.—Con.		
2433	Union Brand King's Favorite	Royal Oak	Claimed.... Found.....
2395	Union Brand Onion, Potato and Vegetable Grower	Tecumseh	Claimed.... Found.....
2396	Union Brand Pure Bone Meal and Potash	Tecumseh	Claimed.... Found.....
	Armour Fertilizer Works, Chicago, Ill.		
2434	All Soluble	Redford	Claimed.... Found.....
2526	Ammoniated Bone With Potash	Manufacturer's sample	Claimed.... Found.....
2338	Armour's Standard	Blissfield	Claimed.... Found.....
2335	Banner Brand	Blissfield	Claimed.... Found.....
2435	Bone Blood and Potash	Redford	Claimed.... Found.....
2455	Bone meal	Holland	Claimed.... Found.....
2456	Crop Grower	Zeeland	Claimed.... Found.....
2555	Crop Grower	Almont	Claimed.... Found.....
2552	Crop Grower	Niles	Claimed.... Found.....
2405	Fruit and Root Crop Special	Milan	Claimed.... Found.....
2553	Fruit and Root Crop Special	Battle Creek	Claimed.... Found.....

1910, expressed in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash.	Valuation.
0.82	....	1	8	3	$14 30
1.03	10.55	1.35	9.20	3.06	16 47
1.65	....	1.50	8	7	21 39
1.49	9.50	0.54	8.96	9.24	23 53
1.00	21.55	4.38	17.17	3.38	25 84
2.88	....	0.50	8	4	22 64
2.96	11.12	2.40	8.72	5.32	25 67
2.47	....	0.50	6	2	17 21
2.20	8.15	0.98	7.17	2.67	18 22
0.82	....	0.50	8	3	14 10
1.08	8.57	0.48	8.09	3.64	15 75
....	....	0.50	10	8	17 68
....	10.57	0.26	10.31	8.48	18 45
4.11	....	0.50	8	7	30 04
4.21	12.05	1.54	10.51	8.77	35 05
2.47	24	....	....	....	28 29
2.47	24.00	....	....	....	28 29
1.23	....	0.50	8	2	14 65
0.98	10.35	0.64	9.71	2.96	16 41
1.23	....	0.50	8	2	14 65
1.05	9.42	1.24	8.18	6.35	18 64
1.23	....	0.50	8	2	14 65
1.20	9.95	0.72	9.23	2.59	16 43
1.65	....	0.50	8	5	19 07
1.45	11.72	2.29	9.43	5.33	20 81
1.65	....	0.50	8	5	19 07
1.65	9.77	0.77	9.00	5.88	21 03

Results of analyses of commercial fertilizers for

Laboratary number.	Trade name.	Locality where sample was taken.	
	Armour Fertilizer Works, Chicago, Ill.—Con.		
2544	Fruit and Root Crop Special	Redford	Claimed.... Found.....
2561	Fruit and Root Crop Special	Zeeland	Claimed.... Found.....
2336	Grain Grower	Ida	Claimed.... Found.....
2457	High Grade Potato	Nunica	Claimed.... Found.....
2337	Phosphate and Potash	Blissfield	Claimed.... Found.....
2467	Star Phosphate	Benton Harbor	Claimed.... Found.....
2468	Steamed Bone Meal	Coloma	Claimed.... Found.....
2339	Sugar Beet Special	Temperance	Claimed.... Found.....
2406	Wheat, Corn and Oats Special	Milan	Claimed.... Found.....
2458	Nitrate of Soda	Muskegon	Claimed.... Found.....
	The Bash Fertilizer Co., Fort Wayne, Ind.		
2527	Bashumus Big Crop Producer	Manufacturer's sample	Claimed.... Found.....
2528	Bashumus Big Truck Grower	Manufacturer's sample	Claimed.... Found.....
	Robert Binder Est., Battle Creek, Mich.		
2469	Binder's Blood and Bone Fertilizer	Battle Creek	Claimed.... Found.....

1910, expressed in parts in one hundred.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
1.65 1.95	.... 11.95	0.50 1.09	8 10.86	5 5.62	$19 07 23 87
1.65 **1.46**	.... 9.85	0.50 1.04	8 8.81	5 6.56	19 07 20 90
1.65 1.69	.... 10.97	0.50 0.56	8 10.41	2 2.35	16 19 19 11
1.65 1.64	.... 10.55	0.50 0.93	8 9.62	10 10.03	23 87 25 66
....	.... 12.00	0.50 0.32	10 11.68	2 3.10	11 92 14 66
....	.... 14.75	0.50 0.34	14 14.41	....	14 00 14 41
1.65 1.69	20 **17.51**	....	....	....	22 07 **20 23**
0.82 0.92	.... 9.15	0.50 0.27	8 8.88	4 4.39	15 06 16 59
0.82 1.00	.... 9.50	0.50 1.18	7 8.32	1 1.28	11 18 13 70
15.63 15.83	....	....	....	....	57 52 58 25
1.60 1.98	.... 10.70	2 0.35	8 10.35	2 3.32	16 61 20 96
1 1.42	.... 11.42	1 0.40	8 11.02	8 9.20	19 76 25 24
5.25 5.29	13.17 15.77	.... 4.52	.... 11.25	0.29 1.60	30 13 34 04

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	James Boland Fertilizer Works, Jackson, Mich.		
2529	Blackman General Crop Brand	Manufacturer's sample	Claimed Found
2437	Blackman Sugar Beet, Onion and Potato	Ypsilanti	Claimed Found
	Buffalo Fertilizer Co., Buffalo, N. Y.		
2459	Ammoniated Bone Black	Coopersville	Claimed Found
2438	Bone Meal	Grand Rapids	Claimed Found
2340	Celery and Potato Special	Reading	Claimed Found
2341	Farmer's Choice	Petersburg	Claimed Found
2439	Garden Truck	Grand Rapids	Claimed Found
2545	Garden Truck	Kalamazoo	Claimed Found
2554	Garden Truck	Kalamazoo	Claimed Found
2342	General Crop	Petersburg	Claimed Found
2460	Ohio and Michigan Special	Coopersville	Claimed Found
2442	Soluble Bone	Grand Rapids	Claimed Found
2559	Soluble Bone	Owosso	Claimed Found
2530	York State Special	Manufacturer's sample	Claimed Found

1910, expressed in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
1.25 2.57	.... 14.00	.... 5.68	7 8.32	1.25 1.45	$12 80 21 44
2.50 **2.28**	.... 11.77	.... 4.78	10 **6.99**	3 3.33	22 08 **20 49**
1.23 1.70	.... 10.36	1 1.74	8 8.62	2.50 2.58	15 33 18 06
2.88 3.06	22 23.65	....	....	....	28 19 30 18
1.64 1.97	.... 9.80	1 0.66	8 9.14	10 10.21	24 03 26 46
0.82 1.07	.... 11.47	1 0.93	8 10.54	5 5.21	16 22 19 85
3.29 **3.06**	.... 9.30	1 0.82	8 8.48	7 7.96	27 23 27 70
3.29 **1.59**	.... 9.75	1 1.65	8 8.10	7 7.94	27 23 **22 23**
3.29 **1.67**	.... 10.65	1 1.16	8 9.49	7 6.92	27 23 **22 74**
....	.... 10.85	1 .90	9 9.95	3 3.46	11 88 13 27
0.82 1.00	.... 12.92	1 2.02	10 10.90	1 1.06	14 38 16 41
....	.... 13.63	1 1.25	14 **12.38**	....	14 00 **12 38**
....	.... 19.60	1 0.72	14 18.88	....	14 00 18 88
1.64 1.67	.... 10.67	1 1.27	9 9.40	5 8.28	20 24 24 01

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Buffalo Fertilizer Co., Buffalo, N. Y.—*Con.*		
2440	Muriate of Potash	Grand Rapids	Claimed Found
2441	Nitrate of Soda	Grand Rapids	Claimed Found
2531	Gleaners Acid Phosphate	Manufacturer's sample	Claimed Found
2387	Gleaners Favorite	Wayne	Claimed Found
2551	Gleaners Favorite	Marine City	Claimed Found
2388	Gleaners General Grower	Wayne	Claimed Found
2389	Gleaners Phosphate and Potash	Wayne	Claimed Found
2390	Gleaners Special	Wayne	Claimed Found
2569	Gleaners Special	Marine City	Claimed Found
	E. Burton, St. Joseph, Mich.		
2486	Meat and Bone Phosphate	St. Joseph	Claimed Found
	Cincinnati Phosphate Co., Cincinnati, O.		
2407	Capital Black Soil Fertilizer	Willis	Claimed Found
2532	Capitol Bone and Phosphate Mixture Wheat Special	Manufacturer's sample	Claimed Found
2408	Capitol Dissolved Phosphate and Potash	Willis	Claimed Found
2409	Capitol Grain and Grass Grower	Willis	Claimed Found

1910, expressed in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
....	....	....	....	48 51.02	$46 08 48 98
15 15.25	....	....	....	....	55 20 56 17
....	.... 17.40	1 1.86	14 15.54	....	14 00 15 54
1.64 **1.50**	.... 9.05	1 0.84	8 8.21	4 3.93	18 28 **17 84**
1.64 1.57	.... 11.87	1 0.90	8 10.97	4 5.28	18 28 22 18
0.82 1.53	.... 9.35	1 0.91	10 **8.44**	1 3.27	14 38 17 58
....	.... 11.86	1 0.98	10 10.88	2 1.95	11 92 12 75
0.82 1.09	.... 9.27	1 0.91	8 8.36	4 **3.22**	15 26 15 82
0.82 1.19	.... 10.85	1 1.15	8 9.70	4 5.17	15 26 19 50
4 4.81	.... 10.20	.... 1.90	15 **8.30**	0.36 0.37	30 07 **27 12**
....	.... 8.30	1 1.72	6 6.58	10 9.84	15 60 16 02
1.60 1.84	.... 16.90	6 5.60	10 11.30	1 1.67	19 25 21 92
....	.... 14.87	1 4.48	10 10.39	4 3.95	13 84 14 18
0.80 0.89	.... 11.40	1 1.08	8 10.32	2 2.77	13 26 16 69

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Cincinnati Phosphate Co., Cincinnati, O.—*Con.*		
2410	Capitol Tobacco, Potato and Beet Grower	Willis	Claimed.... Found.....
2411	Capitol Truck and Tobacco Fertilizer	Willis	Claimed.... Found.....
2563	Capitol Truck and Tobacco Fertilizer	Grand Rapids	Claimed.... Found.....
2412	Capitol Wheat Grower	Willis	Claimed.... Found.....
	Darling & Co., Chicago, Ill.		
2444	Big Potash Brand	Washington	Claimed.... Found.....
2565	Big Potash Brand	Imlay City	Claimed.... Found.....
2470	Chicago Brand	South Haven	Claimed.... Found.....
2445	Farmers' Favorite Brand	Manchester	Claimed.... Found.....
2343	General Crop Brand	Reading	Claimed.... Found.....
2548	General Crop Brand	Imlay City	Claimed.... Found.....
2446	Phosphate and Potash Brand	Mt. Clemens	Claimed.... Found.....
2566	Phosphate and Potash Brand	Almont	Claimed.... Found.....
2419	Pure Bone and Potash	Lansing	Claimed.... Found.....
2471	Pure Ground Bone	Portland	Claimed.... Found.....

1910, expressed in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
0.80 0.84	... 10.00	1 0.64	8 9.36	4 4.30	$15 18 16 84
1.60 **1.23**	... 9.34	1 0.68	6 8.66	6 **5.24**	18 05 18 49
1.60 **1.46**	... 8.57	1 0.92	6 7.65	6 6.92	18 05 20 04
... ...	... 16.30	1 3.38	12 12.92	... ...	12 00 12 92
1.23 1.43	... 11.87	2 1.97	8 9.90	10 **9.53**	22 93 25 10
1.23 1.19	... 12.12	2 2.62	8 9.50	10 **9.44**	22 93 23 98
1.65 1.88	... 12.65	2 2.77	8 9.88	2 2.05	16 79 19 77
2.47 2.45	... 15.06	2 3.25	8 11.81	4 4.16	21 73 26 12
0.82 1.32	... 11.05	2 0.91	8 10.14	6 **5.68**	17 58 20 82
0.82 1.22	... 11.60	2 1.68	8 9.92	6 6.06	17 58 20 90
... ...	... 12.54	... 1.42	10 11.12	2 **1.62**	11 92 12 68
... ...	... 11.07	... 0.56	10 10.51	2 1.94	11 92 12 37
2.14 **1.14**	20.15 27.40	... ...	... ...	6 7.01	29 75 32 86
2.47 3.01	23 27.30	... ...	... ...	... ...	27 49 32 92

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Darling & Co., Chicago.—*Con.*		
2344	Sure Winner	Reading	Claimed Found
2533	10–5 Brand	Manufacturer's sample	Claimed Found
2472	Vegetable and Lawn Fertilizer	Portland	Claimed Found
	German Kali Works, New York, N. Y.		
2534	Kainit	Manufacturer's sample	Claimed Found
2473	Muriate of Potash	Benton Harbor	Claimed Found
2474	Sulfate of Potash	Benton Harbor	Claimed Found
	Grand Rapids Glue Company, Grand Rapids, Mich.		
2461	Grand Rapids Fertilizer	Grand Rapids	Claimed Found
	Grange Fertilizer Co., Detroit, Mich.		
2345	All Crops Special Fertilizer	Carlton	Claimed Found
2346	Complete Manure	Ida	Claimed Found
2347	Corn, Oats and Grass Fertilizer	Carlton	Claimed Found
2535	High Grade Concentrated Wheat Manure	Manufacturer's sample	Claimed Found
2348	Potato and Vegetable Fertilizer	Carlton	Claimed Found
2497	Wheat Fertilizer No. 1	Davison	Claimed Found

1910, expressed in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
0.82 0.86	.... 10.75	2 1.95	8 8.80	3 3.09	$14 70 15 72
....	.... 10.95	.... 0.47	10 10.48	5 **4.15**	14 80 **14 46**
3.30 **2.89**	.... 12.54	2 1.04	8 11.50	7 7.02	26 67 29 29
....	....	....	....	12 12 08	11 52 11 59
....	....	....	....	50 52 80	48 00 50 65
....	....	....	....	48 47.85	46 08 **45 95**
2 2.73	.... 17.25	6 2.82	6 14.43	1 **0.30**	16 72 25 89
1.03 1.02	10 10.42	.... 0.18	8 9.61	2 2.26	14 51 15 86
0.82 0.90	9 9.67	.... 0.60	7 9.07	1 1.46	11 78 14 03
1.65 1.75	10 10.87	.... 0.85	8 10.02	2 2.10	16 79 18 82
1.23 1.15	11 11.80	.... 0.86	9 10.94	2 1.97	16 25 17 40
0.82 1.04	10 10.89	.... 0.88	8 10.01	3 3.05	14 70 17 12
....	16 17.65	.... 2.28	14 15.37	....	14 00 15 37

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Grange Fertilizer Co., Detroit, Mich.—*Con.*		
2413	Wheat Fertilizer With Potash	Milan	Claimed Found
	Hirsh, Stein & Co., Chicago, Ill.		
2349	Calumet Bone Black Grain Grower	Carlton	Claimed Found
2414	Calumet Bone Phosphate and Potash	Maybee	Claimed Found
2350	Calumet Corn and Wheat Grower	Adrian	Claimed Found
2498	Calumet Fruit and Truck Grower	Owosso	Claimed Found
2351	Calumet Grain Grower	Strasburg	Claimed Found
2572	Calumet High Grade Bone Phosphate and Potash	Adair	Claimed Found
2352	Calumet High Grade Garden and Vegetable Grower	Hillsdale	Claimed Found
2353	Calumet Potato, Tobacco and Onion Grower	Adrian	Claimed Found
2354	Calumet Pure Bone Meal	Hillsdale	Claimed Found
2536	Calumet Special Grape Fertilizer	Manufacturer's sample	Claimed Found
2475	Calumet Special Potato, Tobacco and Onion Grower	Benton Harbor	Claimed Found
2558	Calumet Special Potato, Tobacco and Onion Grower	Coloma	Claimed Found
2355	Calumet Special Pure Bone Meal and Potash	Deerfield	Claimed Found

1910, expressed in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid. Total.	Phosphoric Acid. Insoluble.	Phosphoric Acid. Available.	Potash.	Valuation.
....	12 13.87	.... 1.88	10 11.99	2 2.50	$11 92 14 39
2.06 2.08	.... 10.72	1 0.50	8 10.22	1.50 2.31	17 42 20 30
....	.... 13.50	1 1.22	10 12.28	2 2.11	11 92 14 31
0.82 0.98	.... 10.32	1 1.18	8 9.14	4 4.77	15 26 17 80
4.10 **3.61**	.... 10.27	1 0.83	8 9.44	7 7.11	30 21 **29 90**
1.60 1.77	.... 10.35	1 0.74	8 9.61	2 2.45	16 21 18 78
....	.... 12.45	1 0.51	10 11.94	5 5.21	14 80 16 94
2 **1.51**	.... 8.32	1 0.78	8 **7.54**	6 7.59	21 52 **20 69**
1.60 1.76	.... 10.90	1 0.91	8 9.99	5 5.21	[illegible] 09 21 83
2.40 2.42	22.8 26.40	....	....	....	26 07 30 03
0.82 0.90	20 22.70	.... 1.00	.... 21.70	8 8.80	26 70 29 92
1.60 **1.46**	.... 9.92	1 1.06	8 8.86	10 **8.67**	23 89 **22 98**
1.60 1 77	.... 11.05	1 1.44	8 9.61	10 **9.00**	23 89 25 35
0.82 1.25	20 23.35	....	....	4 4.25	22 86 27 36

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Hirsh, Stein & Co., Chicago Ill.—*Con.*		
2573	Calumet Special Pure Bone Meal	Manufacturer's sample	Claimed.... Found.....
2356	Calumet Special 10% Potash Manure	Adrian	Claimed.... Found.....
2499	Calumet Sugar Beet and General Crop Fertilizer	Croswell	Claimed.... Found.....
2415	Calumet Sure Growth Fertilizer	Maybee	Claimed.... Found.....
2391	Calumet Universal Crop Grower	Wayne	Claimed.... Found.....
2357	Calumet Wheat, Corn and Oats Special	Hillsdale	Claimed.... Found.....
2537	Muriate of Potash	Manufacturer's sample	Claimed.... Found.....
	The Jarecki Chemical Co., Sandusky, O.		
2358	Black Soil Special	Rollin	Claimed.... Found.....
2359	C. O. D. Phosphate	Rollin	Claimed.... Found.....
2360	Fish, Phosphate and Potash, Tobacco and Potato Food	Adrian	Claimed.... Found.....
2361	Lake Erie Guano with Phosphate and Potash	Adrian	Claimed.... Found.....
2362	Number One Guano with Phosphate and Potash	Carlton	Claimed.... Found.....
2364	Special Sugar Beet Grower	Blissfield	Claimed.... Found.....
2363	Square Brand Phosphate and Potash	Carlton	Claimed.... Found.....

1910, expressed in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
0.82 1.18	29.77 34.00	....	....	....	$26 84 31 54
0.82 0.98	.... 6.37	0.50 0.32	5 6.05	10 10.90	17 82 20 26
1.23 1.39	.... 13.20	1 2.22	9 10.98	2 2.75	15 85 19 63
1 0.93	.... 10.95	1 1.79	8 9.16	2 2.08	14 00 15 30
0.80 0.84	.... 9.22	1 1.34	7 7.88	1 1.15	11 30 12 61
0.82 1.25	.... 10.10	1 0.76	8 9.34	3 3.62	14 30 17 72
....	....	....	....	50 54.36	48 00 52 19
....	.... 7.80	1 1.77	6 6.03	10 10.98	15 60 16 57
....	.... 14.90	1 2.86	12 12.04	....	12 00 12 04
0.83 0.94	.... 11.05	1 0.99	8 10.06	4 4.28	15 30 18 03
1.25 1.40	.... 11.15	1 2.29	8 8.86	2.50 3.01	15 41 17 83
0.83 1.01	.... 11.52	1 2.02	8 9.50	2 2.42	13 38 16 35
0.83 0.84	.... 9.97	1 1.29	8 8.68	4 4.37	15 30 16 48
....	.... 14.83	1 3.23	10 11.60	2 2.49	11 92 13 99

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	The Jarecki Chemical Co., Sandusky, O.		
2365	Tobacco and Truck Grower	Petersburg	Claimed.... Found.....
2550	Tobacco and Truck Grower	Rollin	Claimed.... Found.....
	Kalamazoo Rendering & Fertilizer Co., Kalamazoo, Mich.		
2538	Celery City	Manufacturer's sample..	Claimed.... Found.....
2476	Kazoo Fertilizer	Kalamazoo	Claimed.... Found.....
	Nitrate Agencies' Co., Chicago, Ill.		
2539	Acid Phosphate "High Grade"	Manufacturer's sample..	Claimed.... Found.....
2519	Muriate of Potash	Coloma	Claimed.... Found.....
2540	Sulfate of Potash	Manufacturer's sample..	Claimed.... Found.....
2477	Nitrate of Soda	Niles	Claimed.... Found.....
	Pioneer Fertilizer Co., Chicago, Ill.		
2478	Pioneer General Crop Grower	Saginaw	Claimed.... Found.....
2500	Pioneer High Grade Acid Phosphate	Brown City	Claimed.... Found.....
2501	Pioneer High Grade Phosphate and Potash	Brown City	Claimed.... Found.....
2541	Pioneer Potato and Vegetable Grower	Manufacturer's sample..	Claimed.... Found.....
2502	Pioneer Truck and Corn Grower	Brown City	Claimed.... Found.....

1910, expressed in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
1.66 1.41	... 12.63	1 2.95	6 9.68	6 5.94	$18 27 21 75
1.66 1.49	... 8.83	1 0.62	6 8.21	6 6.11	18 27 19 82
1 0.91	... 5.75	5 0.91	3 4.84	2 2.00	10 60 10 47
2 3.07	... 8.52	6 2.60	3 5.92	3 4.47	15 64 22 55
... ...	... 18.40	... 0.87	14 17.53	... ...	14 00 17 53
... ...	... ...	... ...	... ...	50 48.18	48 00 46 25
... ...	... ...	... ...	... ...	48 50.42	46 08 48 40
15.5 16.08	... ...	... ...	... ...	... ...	57 04 59 16
1.65 1.83	... 12.55	2 3.48	9 9.07	2 2.03	17 79 19 16
... ...	... 16.70	1 1.84	14 14.86	... ...	14 00 14 86
... ...	... 11.02	1 1.18	10 9.84	4 3.96	13 84 13 64
1.65 1.90	... 11.30	2 0.78	9 10.52	7 8.81	22 59 26 29
0.82 0.92	... 12.40	2 1.18	9 11.22	4 4.06	16 66 18 98

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	The Pulverized Manure Co., Chicago, Ill.		
2420	Wizard Brand Manure	Lansing	Claimed.... Found.....
	The Smith Agricultural Chemical Co., Columbus, O.		
2366	Chicago Fertilizer B. B. & P. Brand	Willow	Claimed.... Found.....
2367	Chicago Fertilizer Calumet Phosphate	Carlton	Claimed.... Found.....
2368	Chicago Fertilizer Potash Special	Erie	Claimed.... Found.....
2369	Chicago Fertilizer, Western Phosphate and Potash	Petersburg	Claimed.... Found.....
2370	Ohio Farmers' Ammoniated Phosphate and Potash	Petersburg	Claimed.... Found.....
2371	Ohio Farmers' Corn, Oats and Wheat Fertilizer	Petersburg	Claimed.... Found.....
2372	Ohio Farmers' Excelsior Phosphate	Carlton	Claimed.... Found.....
2373	Ohio Farmers' Soluble Phosphate and Potash	Petersburg	Claimed.... Found.....
2374	Ohio Farmers' Wheat Maker and Seeding Down	Petersburg	Claimed.... Found.....
	Speidel & Swartz, Grand Haven, Mich.		
2462	Celery Hustler	Grand Haven	Claimed.... Found.....
	Swift & Co., Chicago Ill.		
2417	Bean and Grain Grower	Dundee	Claimed.... Found.....
2376	Complete Fertilizer	Ida	Claimed.... Found.....

1910, expressed in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
1.80 1.58	.... 2.67	.... 0.25	1 2.42	1 0.62	$8 59 8 94
1.23 1.24	.... 10.97	.... 1.31	8 9.66	2 1.99	14 45 16 65
....	.... 13.09	.... 1.65	10 11.44	2 2.34	11 92 13 69
0.82 0.82	.... 11.35	.... 1.84	8 9.51	4 4.09	14 86 17 20
0.82 0.84	.... 11.50	.... 1.75	8 9.75	2 3.24	12 94 16 65
0.82 0.87	.... 11.05	.... 1.64	8 9.41	4 3.97	14 86 17 08
1.23 1.40	.... 12.47	.... 2.14	8 10.33	2 2.00	14 45 18 26
0.82 1.06	.... 11.08	.... 1.22	8 9.86	7 7.12	17 74 21 09
....	.... 13.53	.... 1.91	10 11.62	2 2.28	11 92 13 81
0.82 1.01	.... 10.90	.... 1.95	8 8.95	2 2.11	12 94 15 48
6 6.52	.... 4.85	0.69 0.70	3.17 4.15	1.25 2.07	26 73 30 41
0.82 0.97	.... 11.40	1 1.46	8 9.94	3 3.09	14 30 17 06
1 1.30	.... 11.00	1 2.15	8 8.85	1 1.37	13 04 15 81

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Swift & Co., Chicago, Ill.—*Con.*		
2377	Dissolved Animal Bone and Potash	Petersburg	Claimed.... Found.....
2479	Garden City Phosphate	East Lansing	Claimed.... Found.....
2574	Ground Steamed Bone	Manufacturer's sample	Claimed.... Found.....
2378	Onion, Potato and Tobacco	Jackson	Claimed.... Found.....
2480	Potato, Celery and Onion Grower	Capac	Claimed.... Found.....
2375	Pure Bone Meal	Hillsdale	Claimed.... Found.....
2560	Pure Bone Meal	Grand Rapids	Claimed.... Found.....
2447	Pure Lawn Fertilizer	Grand Rapids	Claimed.... Found.....
2379	Special Phosphate and Potash	New Boston	Claimed.... Found.....
2482	Sugar Beet Grower	Capac	Claimed.... Found.....
2481	Sugar Beet Special	Manufacturer's sample	Claimed.... Found.....
2380	Superphosphate	Hillsdale	Claimed.... Found.....
2381	Truck Grower	Reading	Claimed.... Found.....
2382	Vegetable Grower	Jackson	Claimed.... Found.....

1910, expressed in parts in one hundred.—Con.

Nitrogen.	Phosphoric Acid.			Potash.	Valuation.
	Total.	Insoluble.	Available.		
0.57 1.38	.... 20.75	2 1.32	18 19.43	4 4.48	$24 74 29 34
....	.... 14.75	1 0.58	14 14.17	....	14 00 14 17
1.65 1.92	20 23.35	....	....	....	22 07 25 75
1.65 1.67	.... 10.60	2 0.76	8 9.84	7 6.99	21 59 22 99
0.82 1.09	.... 8.65	1 1.28	5 7.37	10 8.94	18 02 20 47
2.50 3.69	25 23.00	....	....	....	29 20 31 98
2.50 2.59	25 25.75	....	....	....	29 20 30 13
3.75 4.18	23 25.25	....	....	....	32 20 35 58
....	.... 12.40	1 1.25	10 11.15	2 1.93	11 92 13 00
2. 0 1.83	.... 11.27	2 1.14	8 10.13	5 6.35	22 80 23 42
0.82 1.02	.... 8.90	1 0.88	8 8.02	3 3.65	14 30 15 63
1.65 1.77	.... 12.32	2 3.64	8 8.68	2 2.35	16 79 18 92
0.82 1.07	.... 11.10	1 1.05	8 10.05	4 4.17	15 26 18 41
3.29 3.61	.... 11.37	2 0.68	9 10.69	10 11.51	31 51 35 29

Results of analyses of commercial fertilizers for

Laboratory number.	Trade name.	Locality where sample was taken.	
	Tuscarora Fertilizer Co., Chicago, Ill.		
2383	Ammoniated Phosphate	Ida	Claimed.... Found.....
2562	Ammoniated Phosphate	Zeeland	Claimed.... Found.....
2384	Bone and Potash	Ida	Claimed.... Found.....
2503	Michigan Special	Sebewaing	Claimed.... Found.....
2483	Tuscarora Bone Phosphate	New Buffalo	Claimed.... Found.....
2484	Tuscarora Fruit and Potato	Coloma	Claimed.... Found.....
2547	Tuscarora Fruit and Potato	New Buffalo	Claimed.... Found.....
2485	Tuscarora Garden	Coloma	Claimed.... Found.....
2463	Tuscarora Standard	Zeeland	Claimed.... Found.....
2556	Tuscarora Standard	Three Oaks	Claimed.... Found.....
2557	Tuscarora Standard	New Buffalo	Claimed.... Found.....
2464	Wolverine Special	Zeeland	Claimed.... Found.....
	Wulchet Fertilizer Co., Dayton, O.		
2542	Onion and Truck Fertilizer	Manufacturer's sample	Claimed.... Found.....

USE OF COMMERCIAL FERTILIZERS.

It is not possible for any man to predict with certainty what the return will be from the use of any particular fertilizer, because so much depends on the season, the physical condition of the soil, etc. It is safe to assume that a soil is lacking in something when it fails to produce a good, average crop, say 40-50 bushels of shelled corn or 25-30 bushels of wheat per acre. For all soils under good climatic conditions should be able to produce the above amounts of grain when properly handled. The failure of a soil to yield average crops may be due to several causes, among which may be mentioned the following: improper drainage, improper tillage, unfavorable climatic conditions, lack of moisture, lack of humus, acidity, lack of available plant food.

It will be readily seen from this that only one of these conditions can be remedied by the addition of commercial fertilizers. If the other conditions exist, they should, as far as possible, be corrected before any form of commercial plant food is used. It will be readily seen that all of these conditions except one, are within the power of man to control, at least to a certain degree.

Drainage. It is not an uncommon sight, especially in the spring, to see large areas in fields where the water is standing anywhere from a few inches to a foot or more in depth. In such cases it is late in the season before the land is in a condition to be worked; consequently if a crop is sown, it is late in getting started and furthermore, such places are liable to be flooded with every heavy rain. In some soils the water may not stand upon the surface, but come to a level within a few inches of the surface. Such soils can be benefitted only by a drainage system that will carry away the excess of water. Commercial fertilizers cannot take the place of drainage.

Cultivation. The advantages to be derived from cultivation are many. It keeps the ground in good physical condition, makes available some of the insoluble plant food, kills weeds, and when done at the proper time, conserves soil moisture. Commercial fertilizers cannot take the place of cultivation.

Unfavorable climatic conditions are beyond the control of man. Commercial fertilizers cannot overcome unfavorable climatic conditions.

Moisture. The soil moisture may be controlled to a certain extent by judicious rolling and cultivation. Commercial fertilizers cannot compensate for lack of moisture.

Humus is decayed and decaying organic matter. It plays an important part in the fertility of a soil. It helps the physical condition, conserves moisture, makes available some of the insoluble plant-food. Humus may be supplied by adding barnyard manure or by turning under green manures, such as clover, cowpeas, rye, etc. Commercial fertilizers do not add humus to the soil.

Soil Acidity. Soils may become acid as a result of the decomposition of organic matter and possibly from other causes. Some plants are particularly sensitive to an acid condition of the soil, especially alfalfa

and clover. Soil acidity may be corrected by the use of some form of lime. The forms of lime generally used for agricultural purposes are the following: Burned or stone lime, air-slaked lime, ground lime stone, and land plaster. Burned lime is the most active form of lime and is quite caustic. It is usually obtained in lumps and must first be slaked before it can be applied. This is conveniently done by putting it in small piles and sprinkling just enough water over it so that it will break down into a fine powder, or the piles may be covered with moist earth and allowed to stand until it breaks down into a powder, when it may be spread with a shovel.

When the stone lime is exposed for some time to the atmosphere, it gradually takes up moisture and breaks down into a powder form, when it is known as air-slaked lime. Lime can be purchased in this form and it may be applied with a drill or lime spreader. An objectionable feature to the use of either of these two forms is their causticity, which renders them disagreeable to handle.

The ground lime stone is now being prepared in this state and can be obtained at reasonable rates. This form of lime is not as active as the two mentioned above, but it has the same effect upon the soil and undoubtedly is much safer to use, especially when the lime must be applied immediately before the seed is sown. One hundred pounds of ground lime stone is equal in neutralizing power to fifty-six pounds of burned lime or seventy-four pounds of air-slaked lime.

Land plaster was formerly used to quite a large extent both in the United States and Canada, but at the present time its use is very limited. Since the lime in land plaster is already fully saturated with the acid radicle of sulphuric acid, it cannot neutralize soil acidity, and its beneficial effects are supposed to be due to its power of making available some of the insoluble potash compounds in the soil.

Marl is another form of lime that is more or less abundant in the state. It is often found underlying marshes and along shores of small lakes, and when it can be gotten out at not too great an expense, it is a valuable form of lime to use for agricultural purposes. The lime is in the form of the carbonate, the same as the lime rock and it varies in purity from 50% to 60% calcium carbonate to nearly 100%. On account of the large amount of water which it contains in its natural condition, it is not profitable to transport it for any considerable distance without first drying it.

Available Plant Food. The availability of the plant food in a soil is dependent upon several factors, the most important being those mentioned above. When all of these conditions have been fulfilled, it may then be profitable to use commercial fertilizers. It is a self-evident fact that the farmer who sells the greater part of the product of his farm is slowly but surely depleting the stock of plant food in the soil, and it is not unreasonable to assume that under such conditions the time will come sooner or later when the soil will become unproductive for an actual lack of available plant food. Such deficiency may be supplied by commercial fertilizers. The dairyman or stockman who feeds the product of his farm to his cattle and judiciously cares for the manure and puts it all back on the farm, need have but little fear of depleting the store of available plant food in the soil, because the actual

fertility that is sold in the form of butter-fat or beef is not very great. Besides the concentrated feeds that are bought would probably compensate for the loss of fertility in the sale of the products.

The amounts and kind of commercial fertilizers to be used depend upon the kind and condition of the soil and also upon the crops to be grown. No specific recommendations can be made at this time and we shall only attempt to give some general directions for a few of the more common soil types in the state. In certain sections of the state very large areas are made up almost exclusively of light, sandy soil, and they are generally referred to as unproductive soils. There are, however, many cases on record where, by a wise method of handling, these soils have been made very productive. Undoubtedly the greatest need of such soil is organic matter or humus and this is probably more easily supplied, at least in the beginning, by turning under green manures. These soils must be well supplied with organic matter at all times, since it betters the physical condition and greatly increases the water-holding capacity.

Commercial fertilizers are very liable to meet with failure on such soils unless the humus supply is kept up. Farmers' Bulletin No. 323 of the United States Department of Agriculture, Washington, D. C., recommends methods for handling these soils, based upon observations made in Michigan, Wisconsin and Minnesota. This bulletin may be obtained by applying at the United States Department of Agriculture.

These soils are quite generally deficient in nitrogen, but this may and should be supplied very largely by turning under legumes, as most of these soils grow clover very successfully.

Whether any forms of phosphoric acid or potash should be added will depend very largely upon the crops grown and should be determined by actual experiment.

Clay soils are universally spoken of as strong soils and they will generally respond to good cultivation methods for a good many years without any apparent decline in fertility. What is true of the sandy soils in regard to humus is equally true of the clay soils, though the effects of a lack of humus is evidenced in a different way. Clay soils deficient in humus become heavy and soggy, and are very liable to puddle after a heavy rain and to bake so hard as to render them almost impossible of cultivation. Humus will correct these faults by making the soil more open and porous, so that the air may circulate more freely and it will prevent puddling and baking. These soils are more liable to be deficient in available phosphoric acid than either of the other essential plant-food elements. The kind and extent of fertilization will depend upon the kind of crops to be grown.

The loam soils are gradations between the heavy clays and light sands and are generally productive soils. The same general considerations will apply to these soils as to the clays and sands.

Muck soils are almost invariably deficient in potash and as a rule will respond to applications of this material. This has been conclusively demonstrated by experiments carried on in our neighboring states as well as in our own state. Muck soils also generally respond to applications of barnyard manure.

GRADE DAIRY HERD.

BY A. C. ANDERSON.

Bulletin No. 264.

The present Grade Dairy Herd which is maintained at the college was installed in the fall of 1904 by Director R. S. Shaw then Professor of Animal Husbandry. About a year later the writer was placed in charge of the work and is still continuing in that capacity.

In 1906 the first report was published in bulletin 238. As the edition of bulletin 238 is nearly exhausted, and as some of the data contained therein is necessary to a proper understanding of this report a portion of the material of the former report appears again in this.

In maintaining a grade dairy herd at this institution two chief ends are sought. First and foremost to show objectively how the common dairy stocks of this state can be improved as to quantity and quality of milk production by a rational and continued system of up-grading; and second to show the effect of careful feeding and management upon average, common, or even inferior dairy animals. While the stocking of farms with pure-bred dairy animals is desirable and strongly advised, it is generally recognized that the great mass of improvement among dairy cattle must come from intelligent up-grading. In selecting the foundation stock for a grade dairy herd attention was given first to the health and general physical characteristics of each individual selected. Care was also taken to secure animals which should be fairly uniform. To accomplish the desired ends with the material available in the Michigan markets it was thought best to purchase twenty Shorthorn grade cows. While none of these cows possessed a large percentage of Shorthorn blood, they all had enough to give the evenness and uniformity sought in the foundation herd. For breeding purposes the herd was divided into four groups or sub-herds of five animals each. One of these groups is being bred continuously to Jersey bulls, and the female progeny bred in the same line. Another of the groups is being bred continuously to Holstein bulls and the female progeny bred in the same line. The third group being bred in the same way to Guernsey bulls and the fourth to Shorthorn bulls.

The heifers which have come to maturity have been retained in the herd and at the present time have replaced all the original animals, but while the records of these grade heifers are being kept they form no part of this report.

The execution of the plans is requiring time and results are accumulating slowly, even more slowly than was at first anticipated. Some of the best animals in the herd left no female progeny, while two or three of the poorest left female progeny only. Along with the usual handicaps that every dairyman must endure came contagious abortion, a disease while less to be dreaded than tuberculosis still is capable of even more serious results in reducing the milk product and consequent profit as well as the number of progeny of a herd. In an attempt to stamp out this disease some drastic measures were adopted by the veterinarians in charge which not only failed to ac-

complish the desired end but which still further decreased the production of the animals so treated. The matter is mentioned here because contagious abortion is today far too prevalent in our dairy herds, and despite many advertised and published statements to the contrary, veterinary practice is none too successful in its eradication or control.

It was the original plan to so handle the herd that each animal would freshen once each year. But since this could not always be brought about within exact dates the year was taken as the unit of time instead of the period of lactation. In ascertaining the product of each cow the following plan is used:

The milk from each cow is weighed, recorded, and sampled, at each milking. The composite samples are tested for butter fat at the close of each week. The pounds of milk produced by a cow in a week multiplied by the per cent of fat gives the pounds of butter fat for the week. The pounds of butter fat increased by one-sixth of itself gives the pounds of butter. The skim-milk is estimated at 80 per cent of the whole milk. This estimate for skim-milk is rather low, it being customary at creameries to allow 85 per cent of whole milk for skim-milk.

At the close of the first year the records for twenty animals were reported. Before the close of the second year the herd was reduced to sixteen head. No. 28 having died of pericarditis, and No. 30 being afflicted with an abscess that necessitated her removal from the milking herd. No. 32 failed to breed and was sold for beef, while No. 31 afflicted from the outset with a peculiar milking difficulty which gradually grew worse was removed from the herd. Five other cows were added to the herd, as follows: No. 33, 34, 35, 36, 37. During the next two years from one cause or another the herd was gradually reduced, the chief reason being the increasing number of cattle at the college and our inability to provide adequate accommodations for so many. In 1909 the last animals of the original herd were sold.

Meanwhile 36 yearly records had accumulated, some of the cows having one record, some two and some three.

In Table 1 which follows the yearly yields for each cow are shown. In column one the number of the cow is given, the cows being numbered instead of named. The second column gives the total days of lactation, out of a possible 365, for the several lactation periods. In column three the total pounds of whole milk are given. Column four shows the average per cent of butter fat; column five the total pounds of butter fat; column six the pounds of butter; and column seven the pounds of skim milk.

TABLE I.

Number of cows.	Days of lactation.	Pounds of whole milk.	Average per cent butter fat.	Pounds of butter fat.	Pounds of butter.	Pounds of skim-milk.
11	323	7,562	3.69	278.8	325.2	6,049
11	365	6,914	3.70	254.9	297.4	5,531
12	304	5,047	4.23	213.6	249.1	4,038
12	320	5,444	4.11	223.5	260.8	4,355
13	335	7,120	4.54	323.1	376.9	5,696
13	295	6,912	4.14	286.2	333.9	5,530
14	267	7,044	3.81	268.2	312.8	5,635
16	180	2,395	3.62	86.7	101.1	1,916
17	334	7,255	4.44	322.3	376.0	5,804
18	309	7,729	3.48	268.7	313.7	6,182
18	365	6,756	3.74	250.9	292.8	5,405
18	353	7,534	3.66	275.9	321.9	6,027
19	316	4,637	4.48	207.8	242.4	3,709
19	323	5,211	4.72	245.9	286.9	4,169
19	325	4,941	4.52	223.0	260.0	3,953
20	319	5,454	3.67	200.0	233.3	4,363
20	309	5,933	3.81	226.1	263.8	4,746
21	360	5,850	3.16	184.9	215.7	4,680
21	313	5,020	3.72	186.6	217.7	4,016
22	253	5,085	4.08	207.4	242.0	4,068
23	259	5,173	3.97	205.6	239.9	4,138
23	329	6,769	3.76	264.2	308.3	5,415
23	252	5,896	3.84	226.6	264.3	4,717
24	323	7,311	4.08	298.2	347.9	5,849
25	351	6,217	3.73	232.1	270.7	4,974
25	365	7,443	3.67	273.1	318.6	5,954
26	325	6,999	3.82	267.6	312.3	5,599
26	316	6,392	3.93	251.5	293.4	5,113
27	354	5,980	3.86	231.0	269.5	4,784
27	360	5,673	4.04	229.3	267.5	4,538
33	337	6,282	3.86	242.4	282.8	5,025
34	260	6,656	3.73	248.4	289.8	5,325
35	353	8,206	3.69	283.3	330.2	6,565
36	337	6,340	4.38	277.9	324.2	5,072
36	323	7,344	4.30	315.8	368.4	5,875
37	325	5,681	4.61	261.6	305.2	4,545
Average for herd	318	6,228	3.94	245.6	286.6	4,982

For convenience in comparison for the reader as well as for reference in future reports the product of the herd during their first year as reported in bulletin No. 238 is given below as Table 1A.

TABLE IA.

Number of cows.	Days of lactation.	Pounds of whole milk.	Average per cent butter fat.	Pounds of butter fat.	Pounds of butter.	Pounds of skim-milk.
11	323	7,144	3.86	276.86	323	5,715
12	318	5,559	4.41	245.12	286	4,447
13	323	8,113	4.45	361.72	422	6,490
14	363	7,114	3.93	280.29	327	5,690
16	154	1,205	3.43	41.15	48	964
17	361	7,607	4.84	371.15	433	6,084
18	309	7,681	3.53	271.72	317	6,144
19	325	4,796	4.84	232.29	271	3,837
20	360	6,290	3.94	248.58	290	5,031
21	361	6,131	4.24	260.58	304	4,904
22	295	5,417	4.44	219.43	256	4,334
23	293	7,066	3.77	266.58	311	5,653
24	349	7,259	4.25	309.43	361	5,807
25	330	7,423	3.76	279.43	326	5,938
26	346	5,441	3.83	208.29	243	4,352
27	314	5,143	3.95	203.15	237	4,114
28	348	6,872	4.12	283.72	331	5,496
30	316	7,092	3.73	264.86	309	5,673
31	345	6,206	4.04	251.15	293	4,964
32	362	5,620	4.23	237.43	277	4,495
Average for herd	324	6,258.9	4.08	255.65	298.25	5,007

Of the twenty original cows reported in Table 1A, sixteen have reports in Table 1. These sixteen have collectively thirty records. It will be noted that of these thirty records there are but eight which exceed the initial record of the individual cow as shown in Table 1A. Further a comparison of the average as shown in the last line of each table shows 30 pounds more milk and 10 pounds more butter fat per cow for the first year. These cows were purchased for fall freshening in a locality where winter dairying was not generally practiced. Most of the cows had been dry for some little time, quite a few of them a good share of the season. Practically all of them had had a good rest and were carrying sufficient flesh to insure maximum yields after freshening. Then too the management was a little more uniform during the first year than was possible to arrange for during succeeding years. As will be shown in the feeding tables which follow, a smaller amount of silage and some of the other cheaper feeds were available for the herd in subsequent years; these had to be supplemented with grains and other more expensive foods, consequently the profit item was adversely influenced. It will further be observed from a comparison of the two tables that the average number of days of lactation as shown in Table I is slightly less than in Table IA; this would be sufficient to offset the smaller average milk yield. The smaller average production of butter fat is however largely caused by the lower average per cent of butter fat. The average for Table I being 14 per cent lower than for Table IA.

VALUE OF THE PRODUCTS, COST OF PRODUCTION AND PROFIT.

Besides keeping records of the amount of milk given by each cow, daily records were made of the amount of feed consumed by each, so that the entire cost of food for each animal for the year is known. While it would be possible to give the other items of expense entailed by the herd, as cost of care, etc., these are purposely omitted as is also the value of calves and manure. In dairy operations these two groups of items are commonly considered as balancing each other. This they have approximately done in the present case. But as the major item of expense in maintaining a dairy cow is her food, and in view of the extremely intimate relation of food and product, we have eliminated all minor matters in order to better contrast these two main features.

Instead of crediting the herd with the money actually received from the sale of the butter at the college dairy, although more was really received for it than is credited here, the price of butter is fixed at 20 cents net per pound for the entire year. By 20 cents net is meant that this price includes the cost of making. Skim-milk is valued at 20 cents per cwt., this being the price charged for it in experimental feeding conducted at this institution. The values assigned to these products as well as the prices charged for feeds are considerably at variance with market prices for the past few years. However at the time the first report was issued they represented market values fairly well. Since they were used in that report they will be retained in this for convenience in comparison. It will be borne in mind that while receipts for product and cost of foods are both too low the figures representing net profits are much less distorted.

The value of the products of each individual of the herd, as well as cost of production and profit are shown in Table II which follows. In column two will be found the value of butter, in column three the value of skim-milk, while column four gives the total cost of food for each cow. The return for every dollar's worth of food consumed by the cow is shown in column five, the food cost for every 100 pounds of milk produced in column six, and the food cost for every pound of butter in column seven. Column eight gives the total value of products of the cow, being the sum of columns two and three, while column nine shows the profit or loss over food for the entire year.

In considering cost of food, the entire amount consumed by the animal during the whole year is taken, and not simply the portion eaten while in lactation.

TABLE II.

Number of cows.	Value of butter.	Value of skim-milk.	Total cost of food.	Return for $1.00 worth of food.	Food cost for 100 lbs. milk.	Food cost for 1 lb. butter.	Total value of products.	Profit over food.
11	$65 04	$12 09	$39 57	$1 95	$0 52	$0.121	$77 13	$37 56
11	59 48	11 06	35 60	1 98	51	.119	70 54	34 94
12	49 83	8 08	32 66	1 77	64	.131	57 91	25 25
12	52 16	8 71	32 92	1 85	60	.127	60 86	27 95
13	75 38	11 39	38 11	2 27	53	.101	86 77	48 66
13	66 78	11 06	32 70	2 38	53	.098	77 84	45 14
14	62 56	11 27	36 07	2 04	51	.115	73 83	37 76
16	20 21	3 83	20 83	1 15	87	.206	24 04	3 21
17	75 19	11 61	37 25	2 33	51	.099	86 80	49 57
18	62 71	12 36	40 18	1 86	52	.149	75 07	34 89
18	58 56	10 81	33 93	2 05	50	.116	69 37	35 44
18	64 38	12 05	36 52	2 09	48	.113	76 43	39 91
19	48 49	7 42	32 33	1 75	69	.133	55 91	23 58
19	57 37	8 34	32 02	2 05	61	.111	65 71	33 69
19	52 00	7 90	32 67	1 83	66	.125	59 90	27 23
20	46 67	8 73	35 18	1 57	64	.150	55 40	20 22
20	52 75	9 49	38 98	1 59	66	.148	62 24	23 26
21	43 14	9 36	21 95	2 39	38	.101	52 50	30 55
21	43 54	8 03	36 41	1 69	72	.167	51 57	15 16
22	48 40	8 14	29 95	1 88	59	.123	56 54	26 59
23	47 98	8 28	29 89	1 88	57	.124	56 26	26 27
23	61 66	10 83	36 39	1 99	53	.117	72 49	36 10
23	52 86	9 43	27 75	2 25	47	.122	62 29	34 54
24	69 57	11 70	36 82	2 20	50	.106	81 27	44 45
25	54 14	9 95	34 15	1 87	54	.126	64 09	29 94
25	63 72	11 91	37 36	2 02	50	.116	75 63	38 27
26	62 46	11 20	39 08	1 88	57	.125	73 66	34 58
26	58 68	10 23	37 24	1 85	58	.126	68 91	31 67
27	53 91	9 57	32 01	1 98	53	.122	63 48	31 47
27	53 50	9 08	35 02	1 78	60	.131	62 58	27 56
33	56 56	10 05	35 97	1 85	57	.127	66 61	30 64
34	57 96	10 65	24 64	2 78	37	.088	68 61	43 97
35	66 04	13 13	40 80	1 94	49	.123	79 17	38 37
36	64 84	10 14	35 84	2 09	56	.110	74 98	39 14
36	73 68	11 75	36 11	2 36	49	.098	85 43	49 32
37	61 04	9 09	36 26	1 93	63	.118	70 13	33 87
Average for herd	$57 32	$9 96	$34 19	$1 96	$0 55	$0.119	$67 28	$33 09

An examination of the table shows that the value of butter produced by a single cow ranged from $20.21 for No. 16 to $75.38 for No. 13 the average being $57.32. The value of skim-milk ranged from $3.83 to $13.13 with an average of $9.96. The total value of products ranges from $24.04 to $86.80 with $67.28 as the average.

The lowest cost of maintaining a cow for the year was $20.83 while the highest was $40.80 with an average of $34.19 for the whole number.

In the matter of net profits over food No. 16 falls the lowest with only $3.21 to her credit while No. 17 has $49.57. The herd average being $33.09. The food cost per cwt. of milk was 55 cents and the food cost per pound of butter 11.9 cents.

In reviewing these figures the reader will bear in mind that the feed prices are not those prevailing during the past two or three years, neither are the prices allowed for product at all comparable with those received throughout the state. In a general way however an advance in the price of one commodity has been accompanied by a corresponding advance in the price of the other. We will again remind the reader that the product and maintenance of the animals were expressed in terms of money value mainly as a convenient means of comparison, and consequently the food and product values assigned in the first report must be used in this.

Table IIA which follows is taken from the first report and shows the value of products, the cost of production, and profits for the first year.

TABLE IIA.

Number of cows.	Value of butter.	Value of skim-milk.	Total cost of food.	Return for $1.00 of food.	Food cost for 100 lbs. milk.	Food cost for 1 lb. butter.	Total value of products.	Profit over food.
11	$64 59	$11 43	$39 23	$1 93	$0 54	$0.121	$76 02	$36 79
12	57 18	8 89	20 99	2 27	52	.101	66 07	37 07
13	84 34	12 98	36 71	2 65	45	.087	97 32	60 61
14	65 93	11 38	38 47	2 01	54	.117	77 31	38 87
16	9 66	1 93	21 47	54	1 78	.444	11 59	19 88
17	86 64	12 17	38 52	2 56	50	.088	98 81	60 29
18	63 39	12 29	31 18	2 42	40	.098	75 68	44 50
19	54 12	7 67	33 02	1 87	68	.122	61 79	28 77
20	57 32	10 06	39 29	1 71	62	.135	67 38	28 09
21	60 79	9 80	36 30	1 94	59	.119	70 59	34 29
22	51 12	8 67	26 64	2 24	49	.104	59 79	33 15
23	62 29	11 30	31 76	2 31	44	.121	73 59	41 83
24	72 15	11 61	36 45	2 29	50	.101	83 76	47 31
25	65 22	11 88	34 29	2 24	46	.105	77 10	42 81
26	48 68	8 70	31 28	1 83	57	.128	57 38	26 10
27	47 46	8 23	29 09	1 91	56	.122	55 69	26 60
28	66 11	10 99	32 42	2 37	47	.098	77 10	44 68
30	61 80	11 35	29 14	2 51	41	.094	73 15	44 01
31	58 64	9 93	32 65	1 10	52	.111	68 57	35 92
32	55 46	8 99	34 51	1 87	61	.124	64 45	29 94
Average for herd	$59 64	$10 01	$33 07	$2 11	$0 52	$0.110	$69 65	$36 58

FEEDING AND MANAGEMENT.

To enable the reader to answer many of the questions that will naturally arise relative to the feeding of the herd we shall take up this matter in some detail.

In conducting feeding experiments in which the cost of food is an item for consideration, especially if these experiments are to extend over a series of years, it is advisable to establish at the outset a scale of prices of values for the different feeds to be used. The prices adopted are arbitrary and are necessarily those used in the first report:

SCHEDULE OF FEEDS AND PRICES.

Clover hay	$5 00 per ton.
Corn silage	2 50 per ton.
Green corn	2 00 per ton.
Succotash	1 50 per ton.
Roots	2 00 per ton.
Corn meal	20 00 per ton.
Corn and cob meal	16 00 per ton.
Wheat bran	18 00 per ton.
Oats	20 00 per ton.
Dried beet pulp	15 00 per ton.
Dried molasses beet pulp	16 50 per ton.
Gluten feed	20 00 per ton.
Oil cake	28 00 per ton.
Cotton seed meal	26 00 per ton.
Pasture for season	5 00 per ton.

It has been the plan to handle the herd in as uniform a manner as possible, making variations only in amounts of feed as demanded by the milk yield, the stage of lactation, and the individual peculiarities of the animal. They were all kept in good milking condition, but were not allowed much increase in live weight except toward the close of their milking periods and while dry. So far as it could be controlled each cow was allowed to go dry from six to eight weeks.

The regular winter ration of the cows was corn silage, hay, and grain, supplemented at times by mangolds. During the summer they had some pasture and grain, supplemented by silage, succotash, or green corn as the condition of the pasture, the milk flow, and the maturity of the soiling crop dictated or permitted.

In Table III are given the pounds of food consumed by each cow, arranged as to kinds. The costs of grain, roughage, and pasture are given separately. For convenience roots are classed under roughage. By the use of the "Schedule of Prices" the cost of any item of roughage or grain for any cow may be obtained.

Table IIIA which follows is taken from the first report and shows the food consumed by the original herd in producing the product and values reported in Tables IA and IIA.

TABLE III.

Number of cows.	Pounds of food consumed.											Cost of food consumed.			
	Grain mixture No. 4.	Grain mixture No. 5.	Grain mixture No. 8.	Grain mixture No. 9.	Grain mixture No. 10.	Beet pulp.	Silage.	Hay.	Succotash.	Green corn.	Roots.	Cost of grain.	Cost of roughage.	Cost of pasture.	Total cost of food.
11	835	1,134				366	6,223	1,355	491	334	660	$19 36	$15 21	$5 00	$39 57
11			345	330	1,220		6,552	1,218			1,660	17 71	12 89	5 00	35 60
12	408	937				356	6,406	1,022	488	334	620	13 12	14 54	5 00	32 66
12		1,080	420				6,666	1,319	350		1,784	14 26	13 66	5 00	32 92
13	511	1,378				356	6,454	1,070	416	322	660	18 42	14 69	5 00	38 11
13		1,470	80				6,859	1,292	350		788	14 85	12 85	5 00	32 70
14		1,965					6,558	1,213	350	36	724	18 87	12 20	5 00	36 07
16	210	418				356	3,302	950	347	184		6 12	9 61	5 00	20 83
17		1,975				69	7,179	1,233	350	39	444	18 97	13 26	5 00	37 23
18	449	1,678				356	6,314	951	488	334	620	20 94	14 24	5 00	40 18
18		1,260	645			69	4,435	1,301	350		1,866	17 54	11 39	5 00	33 93
18		700	1,260			104	6,814	1,542				18 37	13 15	5 00	36 52
19	380	829				356	6,955	1,124	488	334	660	11 81	15 52	5 00	32 33
19		985	360				7,230	1,285	350		1,259	12 79	14 23	5 00	32 02
19			940	195	400	96	7,066	1,247			705	14 30	13 37	5 00	32 67
20	505	1,021				356	5,879	1,457	491	334	660	14 92	15 26	5 00	35 18
20		2,025					8,284	1,516	350		164	19 45	14 53	5 00	38 98
21	211	525				125	4,297	1,109	486	334		7 18	9 77	5 00	21 95
21		80	1,225	445	130	96	6,656	1,190			1,800	17 60	13 81	5 00	36 41
22	410	851				356	5,606	895	488	334		12 33	12 62	5 00	29 95
23	410	763				356	5,644	984	386	334	620	11 47	13 42	5 00	29 89
23		1,429	350				7,122	1,342	350		1,889	16 96	14 43	5 00	36 39
23			570	515	270	96	5,524	983				12 76	9 99	5 00	27 75
24	244	1,765					6,551	1,248	240	226	620	19 41	12 41	5 00	36 82
25	1,066	350				356	5,607	1,096	488	334	620	14 17	14 98	5 00	34 15
25		855	890			181	7,177	1,397	350		1,846	16 44	15 92	5 00	37 36
26		1,675	340			148	7,205	1,292	350		1,259	19 22	14 86	5 00	39 08
26			1,090	220	740	96	7,034	1,172			705	19 10	13 14	5 00	37 24
27	320	973				356	6,436	984	387	311	660	12 58	14 43	5 00	32 01
27		651	980				7,333	1,363	350		1,889	15 31	14 71	5 00	35 02
33		1,025	760				6,833	1,336	350		1,964	16 87	14 10	5 00	35 96
34		1,200	80				3,928	761	350		312	12 26	7 38	5 00	24 64
35		1,023	1,135				7,504	1,555	350		1,964	20 32	15 48	5 00	40 80
36		1,010	770				6,771	1,342	350		1,960	16 81	14 03	5 00	35 84
36			650	485	830	96	6,688	1,441				18 43	12 68	5 00	36 11
37		970	840				6,833	1,333	350		1,964	17 17	14 09	5 00	36 26
Average for herd	Average grain 1,650					141	6,386	1,219	316	114	926	$15 78	$13 41	$5 00	$34 19

TABLE IIIA.

Number of cows.	Pounds of food consumed.										Cost of foods consumed.			
	Grain mixture No. 1.	Grain mixture No. 2.	Grain mixture No. 3.	Grain mixture No. 4.	Grain mixture No. 5.	Silage.	Hay.	Succotash.	Green corn.	Roots.	Cost of grain.	Cost of roughage.	Cost of pasture.	Total cost of food.
11	1,525	277	135	....	....	10,337	1,067	124	288	1,190	$17 13	$17 10	$5 00	$39 23
12	772	247	174	96	15	6,521	1,291	116	278	542	11 71	12 29	5 00	29 00
13	1,016	297	172	394	....	8,611	1,227	119	278	347	17 17	14 54	5 00	36 71
14	1,248	260	189	109	....	9,927	1,361	124	727	700	16 14	17 33	5 00	38 47
16	482	213	52	....	15	5,015	1,176	....	....	505	6 75	9 72	5 00	21 47
17	1,317	227	183	95	....	10,233	1,166	120	640	741	16 35	17 17	5 00	38 52
18	481	291	161	117	432	6,534	1,604	116	278	38	13 59	12 59	5 00	31 18
19	900	287	173	174	....	8,186	1,245	110	218	542	13 84	14 18	5 00	33 02
20	1,529	253	174	36	....	10,046	1,107	119	278	904	17 70	16 59	5 00	39 29
21	1,406	239	166	48	....	8,504	1,102	130	278	1,013	16 52	14 78	5 00	36 30
22	486	292	174	130	....	6,067	1,326	119	278	270	9 81	11 83	5 00	26 64
23	593	279	162	202	255	7,229	1,259	130	238	542	13 70	13 06	5 00	31 76
24	899	288	177	477	....	8,414	1,228	116	278	542	16 95	14 50	5 00	36 45
25	1,071	280	169	60	....	9,002	1,295	120	278	347	14 09	15 20	5 00	34 29
26	967	279	169	94	....	7,466	1,179	120	278	122	13 51	12 77	5 00	31 28
27	678	288	174	118	30	6,862	1,296	115	212	347	11 63	12 46	5 00	29 09
28	784	283	169	196	45	8,098	1,273	120	278	347	13 40	14 02	5 00	32 42
30	549	296	171	275	....	6,789	1,275	120	278	247	11 84	12 30	5 00	29 14
31	1,062	278	172	34	....	7,970	1,209	120	278	542	13 76	13 89	5 00	32 65
32	1,168	240	167	96	....	8,615	1,283	129	278	495	14 66	14 85	5 00	34 51
Average for herd	(Grain 1,554 lbs.)					8,021	1,248	114	296	516	$14 01	$14 06	$5 00	$33 07

Grain Mixture No. 1.

Dried beet pulp	4 parts.
Oats (ground)	3 parts.
Wheat bran	2 parts.
Gluten feed	1 part.

Grain Mixture No. 2.

Dried molasses beet pulp	2 parts
Wheat bran	1 part.
Gluten feed	1 part.

Grain Mixture No. 3.

Dried molasses beet pulp	4 parts.
Wheat bran	2 parts.
Oil cake	1 part.

Grain Mixture No. 4.

Corn meal	3 parts.
Wheat bran	3 parts.
Oil cake	1 part.

Grain Mixture No. 5.

Dried beet pulp	3 parts.
Corn meal	3 parts.
Wheat bran	6 parts.
Oil cake	2 parts.

Grain Mixture No. 8.

Dried beet pulp	3 parts.
Wheat bran	3 parts.
Corn and cob	2 parts.
Cotton seed meal	1 part.
Linseed meal	1 part.

Grain Mixture No. 9.

Dried beet pulp	3 parts.
Wheat bran	3 parts.
Corn meal	2 parts.
Cotton seed meal	1 part.
Linseed meal	1 part.

Grain Mixture No. 10.

Dried beet pulp	4 parts.
Wheat bran	3 parts.
Cotton seed meal	1 part.
Linseed meal	1 part.

The composition of the different mixtures depended upon the feeding stuffs on hand, the proper balance of the ration, the kind of feeds immediately avail-

able, and in one or two instances the local prices. No attempt was made to demonstrate the superiority of one mixture over another. All cows were fed the same mixture while it was in use.

The average amounts of feeds consumed expressed approximately in tons were:

Grain	.825 tons.
Silage	3.2 tons.
Hay	.609 tons.
Green crops	.214 tons.
Roots and beet pulp	.533 tons.
Pasture	20 weeks.

During the first year which was covered by the former report, the feeding for which is shown in Table IIIA, the average amount of feeds expressed in tons was:

Grain	.75 tons.
Silage	4.00 tons.
Hay	.625 tons.
Green crops	.20 tons.
Roots	.25 tons.
Pasture	20 weeks.

As has before been stated, it will be observed from a comparison of the above approximate figures that the silage could have been increased and the grain decreased with profit. The average cost of food as shown in Table II is $34.19 and in Table IIA $33.07; a difference of $1.12. This increase in cost could have been overcome by a more liberal use of silage and a slight reduction in the grain rations.

INDIVIDUAL COMMENTS.

A word of explanation regarding a few of the individual cows may be of interest, and may aid in the interpretation of their records:

No. 13. This cow was a first class dairy cow, and a very persistant milker. In the third period of lactation she was well started toward equaling her first record, but was very severely affected by the treatments for the eradication of abortion and failed to recover completely from the same.

Cow 34. This cow had a lactation period of only 260 days, but had to be removed from the herd as a result of the treatments above referred to.

Cow 23. Dried up early during her second lactation period due to a temporary illness.

Cow 21 ate $36.41 worth of food during her last lactation period. Of this $17.60 was for grain. This was too much for a cow of her dairy ability. She was a sleek smooth cow with an excellent appetite but with only limited ability for milk giving. For a cow of her type a liberal grain ration is usually unprofitable.

Cow 16. Probably no member of the herd excited more comment than did No. 16 that gave only 1205 pounds of milk during her first period of lactation and closed the first year $9.88 in debt for her years board. Despite a good long rest she gave only 2395 pounds for the second period with $3.21 as the profit over food. At this time she failed to breed and was re-

moved from the herd with an unpaid balance on her total board bill of $6.67. As a business proposition No. 16 should have been sold for beef when she dried up the first year but from an experimental standpoint it was advisable to retain her in the herd.

The cows whose records are herein reported were just ordinary cows, such as could be selected at random almost anywhere in Michigan. Their records as shown here are not phenomenal, but are just fair. The figures as given seem to show that the feeding and care of cows have much to do with a dairy farmers profit.

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MANUFACTURE AND STORAGE OF THE LIME-SULFUR SPRAY.

BY

ANDREW J. PATTEN.

Circular No. 10.

During the past year many requests have been made upon the chemical division of the Experiment Station for some specific information on certain points in regard to the manufacture and storage of the lime-sulfur spray. As the literature on the subject did not furnish the desired information, the investigations reported in the following pages were undertaken during the past summer.

The methods of analysis used and a technical discussion of the investigation are published in Technical Bulletin No. 6.

The possibilities of substituting the lime-sulfur solution, as a summer spray, for the Bordeaux mixture have brought this spray solution very prominently to the front during the past few years. Then too, since Headden has shown that, in Colorado, the continued use of arsenical sprays has resulted, in many cases, in serious injury to the trees and also that the fruit from trees thus sprayed actually show traces of arsenic, this subject has become of very great economic importance.

It is very doubtful, however, that the same conditions existing in Colorado will ever prevail in the State of Michigan on account of the difference in the soil conditions. Yet, the very fact that we are loading up our soils with materials in the form of spray solutions, that are actively poisonous should demand the attention of every one concerned. Although, at the present time, there may not be, and probably is no danger from the use of the arsenic compound, how long can this practice be continued with impunity? How long will it be before the danger and the damage from the excess of arsenic incorporated into the soil may be even greater than the damage due to the insects?

These are questions that should demand the attention of every thinking person and should encourage a search for some less poisonous materials to take the place of the arsenic compounds.

As a contact insecticide and fungicide the lime-sulfur solution is to be highly recommended because it possesses no poisonous properties. As a stomach poison it cannot of course replace the arsenical compounds in combating the sucking insects but it is not beyond reason to believe that some compounds may be found, less poisonous than arsenic, that will prove equally effective.

Lime and sulfur may form several combinations depending upon the amount of sulfur uniting with a definite quantity of lime, or more properly speaking, the element calcium. Theoretically one element of

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[1] This investigation was conducted by Mr. Jas. S. Harris, temporarily connected with this division during the summer of 1910.

calcium may combine with one, two, three, four or five elements of sulfur. Under the conditions that exist in the manufacture of the lime-sulfur spray, most of the lime and sulfur combine in the proportion of 1 to 5, forming a compound known as the penta-sulfide of calcium. If all of the calcium and sulfur combined in this proportion, then in the process of making the spray, the calcium and sulfur should be used in the proportion of one part of the former to four parts of the latter by weight or 1.4 parts of lime to 4 of sulfur. Other compounds are formed, however, in the process and we find by calculation that the theoretical amounts of lime and sulfur that should be used to form the greatest amount of penta-sulfide are one part of lime to 2.28 parts of sulfur by weight. The commercial brands of lime are very seldom pure calcium oxide, as they contain varying amounts of magnesium oxide which reduces the efficiency, and we find that the proportion of one part of lime to two parts of sulfur by weight gives the more satisfactory results.

That the insecticidal value of the solution is due chiefly to the penta-sulfide or higher polysulfides of calcium has been quite definitely established, and it is not probable that the other compounds formed possess any insecticidal or fungicidal value. Consequently in the discussions and tables which follow, only the total sulfur in solution and the amount of sulfur in sulfide form will be considered.

The first point to be considered was that of the composition of some of the limes found upon the Michigan markets. The following brands of lime were used: 1—Kelly Island Lime. 2—A special low magnesia lime put out by the Michigan Lime Co. 3—Crescent Brand of Lime. 4—Ohio and Western Co's Lime. 5—Kelly Island Lime and Transport Co's Lime from White Rock, Ohio. 6—Bay Shore Superior Lime.

These limes showed the following analyses for calcium oxide and magnesium oxide.

Sample.	Calcium oxide. %	Magnesium oxide. %
1	65.70	31.13
2	96.40	0.13
3	74.70	22.47
4	69.22	28.87
5	57.66	41.97
6	86.77	10.21

With two exceptions, two batches of lime-sulfur solution were made up from each brand of lime, one according to the formula 60 pounds of lime 125 pounds of sulfur and 60 gallons of water, designated by the letter A in column one of the table below, the other according to the formula 50 pounds of lime, 100 pounds of sulfur and 50 gallons of water, designated by the letter B.

The solutions were made in barrel lots in a wooden tank built for the purpose. Steam at 45 pounds pressure was used as the boiling agent and the solutions were boiled for one hour. Allowance was made for condensation of the steam so that the volume of the solution at the end

of the boiling would be that called for by the formula used. Samples from each lot were drawn off and freed from sediment by filtration while hot, and when cold were analyzed. The results are expressed in per cent by volume.

Sample.	Total sulfur. %	Sulfide sulfur. %	Calcium oxide. %	Density, degrees Baumé.
1A	18.00	14.32	8.22	18.2
1B	17.58	14.04	7.97	17.8
2A	24.61	20.00	11.96	25.7
2B	21.08	17.17	10.50	22.6
3A	19.96	16.22	9.07	20.4
3B	20.55	16.35	9.63	21.2
4A	17.65	14.03	8.16	17.7
5A	13.65	10.98	6.36	13.3
5B	15.54	12.68	7.24	15.4
6A	20.93	15.93	8.30	21.8

A study of the above two tables shows that the total sulfur in solution bears a relation to the percentage of magnesium oxide in the lime, that is, the higher the percentage of magnesium oxide in the lime used, the lower the percentage of sulfur in solution and the higher the percentage of calcium oxide in the lime used, the higher the percentage of sulfur in solution.

If we arrange the samples according to the amount of total sulfur in solution we have them in the order 2, 6, 3, 1, 4, and 5. If we arrange them according to the amounts of magnesium oxide in the limes used, we have the order 5, 1, 4, 3, 6 and 2, which, with the exception of samples 1 and 4, is the above order reversed. Samples 1 and 4 are very nearly alike, both in the amount of total sulfur in solution and the amount of magnesium oxide in the limes used, and as the variation is small it is not strange that, in the case of these two samples, the order is not reversed. This may have been brought about by a slight variation in the amount of steam condensation in the two cases, which variation would cause a corresponding variation in the concentration of the solutions.

This evident relationship between the amount of sulfur present and the percentage of magnesia in the lime might be due to a harmful effect of the magnesia or it might be due to the fact that when a definite formula is used, such as the 50-100-50 formula, the percentage of calcium oxide is cut down in the exact ratio in which the magnesium oxide is present. That is to say, if we weigh out 50 pounds of lime containing 50 per cent of magnesium oxide, instead of having 50 pounds of calcium oxide we really have only 25 pounds. This matter will be more fully discussed in another place.

From the above data no conclusion can be drawn as to which of the two formulae is the better. In each case, since the lime used is never pure calcium oxide, the sulfur is in excess. In some cases it is found that formula A gives the larger amount of soluble sulfur, and in other

cases formula B gives the largest amount. These variations are not large however, and are probably due to variations in the steam condensation.

AN EXPERIMENT TO DETERMINE THE EFFECT OF MAGNESIUM OXIDE.

From the results of the above experiment we are led to believe that the harmful effect of the magnesium oxide in the lime was due, not so much, to a deleterious effect, (the liberation of sulfur as hydrogen sulfide for instance) as it was to the fact that its presence reduces the quantity of calcium oxide.

If magnesium oxide could unite with sulfur in the same way that calcium oxide does, then its presence would not be harmful but Gibboney[1] has stated that there is practically no reaction between the two materials when boiled together.

In carrying out this experiment three brands of lime were used, showing the following composition:

	Calcium oxide. %	Magnesium oxide. %
1 Kelley Island Lime	74.4	22.5
2 Bay Shore Superior Lime	86.8	10.2
3 J. T. Baker Chemical Co. Lime	99.0	1.0

From each of the first two samples of lime, two lots of lime-sulfur were made up, the first according to the formula 100 grams lime, 200 grams sulfur and 800 grams water, this being the same proportion as the 50-100-50 formula, used in the previous experiment. In the second lot in each case, the amount of lime was increased so that there was half as much calcium oxide as sulfur, the water remaining the same. From the third sample of lime, only one lot was made and in this, the ratio of lime to sulfur was as one to two. Each lot was boiled for one hour in a flask fitted with a condenser so that all the steam was condensed and returned to the flask, thus keeping the volume of the solution constant. The solutions were filtered while hot, allowed to cool and then analyzed.

Limes used.	Formula.	Total sulfur. %	Sulfide sulfur. %	Calcium oxide. %	Density degrees Baumé.
1A	100–200–800	17.34	14.06	8.02	20.7
1B	135–200–800	18.40	14.82	9.00	23.4
2A	100–200–800	17.75	14.28	8.30	21.8
2B	115–200–800	18.42	15.63	8.44	22.1
3B	101–200–800	18.60	15.28	8.85	23.4

[1] Virginia S t Commission. Circular No. 1, New Series.

An examination of the results given in column three of the above table shows that the amount of soluble sulfur is very nearly the same in all cases (1B-2B-3B) where the amount of lime was increased sufficiently so as to give the same amount of calcium oxide in each case and maintain the ratio of 1 to 2 between the calcium oxide and sulfur.

The greatest variation in total sulfur is only 0.2 per cent.

From these results we must conclude that the magnesium oxide does not effect the amount of sulfur going into solution providing enough of the lime is used so that the ratio of one part of calcium oxide to two of sulfur is maintained. It is not good economy, however, to buy lime high in magnesium oxide because more of it must be used and the greater the amount of magnesia the greater will be the amount of sludge, other things being equal. Either of the two formulae (60 pounds lime 125 pounds sulfur and 60 gallons water or 50 pounds lime, 100 pounds sulfur and 50 gallons water) may be recommended, but in all cases it is suggested that an approximate analysis of the lime to be used, be obtained from the manufacturer, and such an amount of it taken that the ratio between the calcium oxide and sulfur shall be as one to two.

The lime should be freshly burned stone lime or hydrated lime as free as possible from other impurities, such as sand, iron, etc. When hydrated lime is used the quantity should be increased by approximately one half.

AN EXPERIMENT TO DETERMINE THE EFFECT OF STORING THE LIME-SULFUR SOLUTION IN CONTACT WITH THE SEDIMENT.

It has been claimed by many and particularly by some manufacturers that if the lime-sulfur solution is stored for any length of time in contact with the sediment a deterioration of the solution takes place due to a separation of some of the sulfur compounds in the form of crystals.

In making the lime-sulfur solution on the farm it is advisable and often quite necessary to get the greater part of it made up before the rush of the spring work comes on and as it is practically impossible to make a satisfactory separation of the solution and sediment without the aid of a rather costly filter press, due to the nature of the sediment, the following experiment was undertaken to find out, whether or not, the sediment does cause a deterioration in the solution. For this purpose several samples of lime-sulfur solution were made up, analyzed and allowed to stand for periods varying from four to seven weeks and again analyzed. For the sake of comparison, filtered portions of each sample were set aside under the same conditions. The results are given in the following table and the samples designated 1A, 2A, etc., are the analyses of the original solutions. 1B, 2B, etc., are the analyses of the solutions that have stood in contact with the sediment. 1C, 2C, etc., are the analyses of the corresponding filtered solutions. Samples 1, 3, 5 and 7 were made according to the formula 60-125-60 and the samples 2, 4, 6 and 8 according to the formula 50-100-50.

Sample.	Time allowed to stand.	Total sulfur.	Sulfide sulfur.	Calcium oxide.	Density degrees Baume.
1A	0 weeks	18.00	14.32	8.22	18.2
1B	6 weeks	17 36	14.00	8.12	17.9
1C	7 weeks	16.40	11.73	8.13	18.4
2A	0 weeks	17.58	14.04	7.95	17.8
2B	6 weeks	16.83	13.63	7.84	17.6
2C	7 weeks	16.62	12.54	8.12	18.1
3A	0 weeks	24.61	20.00	11.96	25.7
3B	6 weeks	21.05	17.53	10.64	23.1
3C	7 weeks	24.34	19.39	11.62	25.8
4A	0 weeks	21.08	17.17	10.50	22.6
4B	5 weeks	20.30	16.26	10.20	21.8
4C	6 weeks	21.02	16.71	10.30	22.8
5A	0 weeks	19.96	16.22	9.07	20.4
5B	5 weeks	19.33	15.58	9.25	20.2
6A	0 weeks	20.55	16.35	9.63	21.2
6B	4 weeks	20.59	16.61	9.46	21.1
7A	0 weeks	13.65	10.98	6.36	13.3
7B	4 weeks	13.31	10.68	6.22	13.0
7C	5 weeks	13.43	10.45	6.40	13.6
8A	0 weeks	15.54	12.68	7.24	15.4
8B	4 weeks	15.44	12.65	6.90	15.4
8C	5 weeks	15.53	12.62	7.08	15.7

With two or three exceptions, which are easily explained, there is very little difference between the filtered and unfiltered solutions after standing for several weeks, neither do they vary much from the original solutions. In the first sample, the filtered solution 1C, was found to be much weaker than the unfiltered, and this is explained by the fact that the stopper of the bottle containing the solution did not fit tightly, thus allowing it to be more or less exposed to the air. Samples 3B and 4B were found to contain less soluble sulfur than the corresponding filtered solutions, and this is explained by the fact that from each of the barrels in which these solutions were stored portions were removed for use by the Horticultural department thus leaving a large air space over the so-

lutions. These results confirm the conclusions of other experiments, viz: that if the lime-sulfur is to be stored for any length of time the containers should be filled completely full and stoppered tightly to exclude all air.

We may conclude then, from the above experiment, that when the lime-sulfur solutions are made according to the formula recommended there is practically no deterioration in the solution when kept in contact with the sediment providing it is stored properly.

Later results have demonstrated that when the lime-sulfur solution is made according to a formula calling for an excess of lime there is liable to be a very considerable deterioration in the solution when kept in contact with the sediment for any length of time, even when stored properly.

The sediment possesses no insecticidal or fungicidal value although it is sometimes beneficial in serving as a marker during the spraying operation. In purchasing commercial solutions it would be poor economy therefore, to buy a solution containing sediment and pay lime-sulfur prices for the comparatively worthless sludge.

EXPERIMENT TO DETERMINE THE EFFECT OF RE-HEATING THE SOLUTION BEFORE USING.

It has been recommended that lime-sulfur solutions which have been allowed to cool should be re-heated before using. In order to determine whether or not there is a distinct advantage in doing this, samples 3, 4 and 8 of the above experiment were used. In samples 3 and 8 the excess of sulfur in the sediment was large; in sample 4 the excess of sulfur was small.

The analyses corresponding to the numbers 3B, 4B and 8B represent the samples that have stood for several weeks in contact with the sediment. The analyses corresponding to the numbers 3D, 4D and 8D represent portions of the same samples that have been re-heated nearly to boiling in contact with the sediment.

Sample.	Total sulfur. %	Sulfide sulfur. %	Calcium oxide. %	Density degrees Baumé.
3B............	21.05	17.55	10.64	23.1
3D............	21.35	17.77	10.61	23.4
4B............	20.30	16.26	10.20	21.8
4D............	20.63	16.59	10.07	22.2
8B............	15.44	12.65	6.90	15.4
8D............	15.42	12.32	6.93	15.3

In the first two samples there is a slight increase in total sulfur and also in sulfide sulfur in the samples that have been re-heated but the

increase is so small that we may safely conclude that, with solutions made according to the formula recommended in this bulletin, there is no advantage to be gained by re-heating the solution before using.

From the results reported in the preceding pages it is plainly evident that the lime-sulfur solutions vary considerably in strength and this is not only true of home-made solutions but also of commercial preparations. In order, then, for the orchardist to do uniform work in his spraying, there should be some simple and fairly accurate means of determining the strength of the solution. The relationship between the density and amount of solids in solution, or in other words the specific gravity, may be taken as a measure of strength. The Baumé hydrometer is most commonly used for determining the density, and the results are expressed in degrees, compared with water at 0 degrees. The strength of the solution, when determined by the hydrometer, should always be made upon the clear liquid, free from sediment. The following table gives the approximate percentage of soluble sulfur in solutions varying from 33 to 17 degrees Baumé, and the dilutions for winter and summer spraying.

Density, degrees. Baumé.	Total sulfur.	Pounds of sulfur in one gallon of solution.	Dilute to fifty gallons.	
			For winter spray.	For summer spray.
	%	lbs.	gals.	gals.
33	26.0	2.7	6¼	1½
32	25.0	2.6	6½	1½
31	24.0	2.5	6¾	1½
30	23.0	2.4	7	1¾
29	22.0	2.3	7½	1¾
28	21.0	2.2	7¾	1¾
27	20.0	2.1	8¼	2
26	19.5	2.0	8¾	2
25	19.0	1.9	9	2
24	18.5	1.8	9½	2¼
23	18.0	1.8	9¾	2¼
22	17.75	1.7	10	2¼
21	17.0	1.6	10½	2½
20	16.75	1.6	10¾	2½
19	16.25	1.5	11¼	2½
18	16.0	1.5	11½	2¾
17	15.5	1.4	12	2¾

SUMMARY.

1. Either of the two formulae (50-100-50 or 60-125-60) used in the foregoing experiments, are recommended for the home-making of lime sulfur solutions. When the lime is very rich in calcium oxide the 60-125-60 is preferable.

2. The lower the amount of magnesium oxide in the lime used the higher will be the per cent of sulfur in solution, other things being equal.

3. An approximate analysis of the lime should be secured and such an amount used so that there shall be one half as much calcium oxide as sulfur.

4. When the solutions are made according to the formulae recommended above, there is no advantage to be gained in filtering the solution before storing.

5. The re-heating of the lime-sulfur solutions before using is not necessary. The increase in soluble sulfur is not sufficient to pay the cost of such an operation.

LIME FOR AGRICULTURAL PURPOSES.

Circular No. 11.

A. J. PATTEN AND J. A. JEFFERY.

A great deal of interest has been exhibited during the past year in the use of lime for agricultural purposes. This circular is issued to supply the demand for information on this subject but the authors do not wish it to be understood as an unqualified recommendation for the use of lime. It is undoubtedly true that there are soils in the state that will be benefited by the use of lime just as there are soils that will be benefited by the use of some form of commercial plant-food but it is equally true that there are many soils that would receive no appreciable benefit from the use of lime. Up to this time no reliable laboratory method has been devised by which this information may be obtained. The litmus paper test has been relied upon for the purpose but it is very untrustworthy since with soil solutions having very finely divided soil particles in suspension the paper is often reddened, while the solution, freed from the soil particles, gives an alkaline or neutral reaction. This phenomenon is explained perhaps, by the fact that the soil particles have a great absorbing power, and the blue litmus dye being more soluble than the red litmus dye, is absorbed leaving the paper red. Perhaps the most reliable indicator of the need of lime is the failure of clover to make a satisfactory stand when all other conditions are favorable.

The practice of using lime is almost as old as agriculture itself. The Chinese were probably the first to use lime on the soil; it was also used by the Romans and by them the practice was introduced into England and France. In England the practice of marling the soil has been followed for centuries, and often with marked results. The first mention of lime in connection with American agriculture is found in the contributions of Ruffin in the "American Farmer" in 1818. Although lime has been used more or less extensively by the farmers of the United States for the past century, its action upon the soil is not generally understood. Lime should never be considered as a fertilizer in the same sense that barnyard manure or commercial fertilizers are. It can never take the place of these materials but should be used in connection with them. Generally speaking, all soils contain a sufficient amount of lime to meet the plant-food requirements of crops for this element for all time, consequently the benefits from lime are shown in another way. It is usually spoken of as an "amendment" or "modifier" because it is capable of correcting conditions that may be inimical to the best growth of plants.

Lime may act upon the soil in three ways, viz.: chemically, physically and biologically.

Chemical Action.—Lime acts upon the insoluble potash compounds in the soil changing them into forms available as plant-food. This action

should not be depended upon, however, as a means of supplying the crops with available potash to the exclusion of artificial fertilizers, for unless the soil contains an almost unlimited supply of potash, we are only hastening the time when the soil will be depleted of this form of plant food. Whether or not lime affects the availability of the insoluble phosphoric acid compounds is a disputed question.

The most important chemical action of lime upon soils is to "correct acidity." Soils that have been cultivated for a great many years may become acid due to the accumulation of organic acids produced by the decomposition of organic matter. Many crops are affected by an acid condition of the soil and in such cases are greatly benefited by the addition of some form of lime or material containing lime such as marl or hardwood ashes.

Physical Action.—Heavy clay soils that puddle and bake after a rain are benefited by the addition of lime. It acts beneficially upon a soil in this condition by binding the fine particles together in "crumbs," thus making the soil more friable and easy of cultivation. It also makes it more open and porous thus facilitating the movement of air and water in the soil. The action of lime on sandy soils is quite the reverse of that on clay soils since it binds together the loose particles of sand and makes the soil more retentive of moisture.

Biological Action.—The decomposition of organic matter added to the soil in the form of barnyard manure, green manure, stubble, etc., is brought about by the action of the numberless bacteria that live in the soil. Certain of the soil bacteria living in connection with the roots of legumes, such as the clovers, vetches, alfalfas, beans and peas are able to take nitrogen from the air and change it into a form that is available to plants. In order for these bacteria to accomplish the most good, the soil conditions must be favorable for their best development, and this condition may sometimes be improved by the addition of some form of lime.

There are several forms of lime that may be used for agricultural purposes and the choice of the form should depend upon the purpose for which it is to be used and also upon the price.

Ground Limestone.—The word lime as ordinarily used, refers to burned lime or calcium oxide, but it is very often used to designate any form of lime without regard to its composition. Limestone in its natural state consists of lime or calcium oxide in combination with carbon-dioxide and is known as carbonate of lime. It usually contains more or less of magnesium carbonate together with some iron, aluminum and sand. It was originally supposed that magnesium limestone was injurious, especially if used on the same soil for several years, but later researches have proven that this belief is untrue and that it is equally valuable as the pure calcium limestone, for use on soils. Good limestone should contain at least 90 per cent calcium and magnesium carbonate.

The availability of the ground limestone depends upon its fineness. It should all pass through a sieve of 80 meshes to the inch. Material coarser than that may remain in the soil for several seasons before becoming available. This form of lime may be applied to the soil in almost any quantity without danger, although it is generally recommended at the rate of 2,000-2,500 pounds per acre.

Burned Lime.—This is also known as "stone lime," "lump lime,"

"quick lime" and "caustic lime." It is produced from the raw lime rock by burning. One hundred pounds of limestone will produce 56 pounds of burned lime. This is the most active form of lime and may be used at the rate of 1,000 to 1,200 pounds per acre. Much larger quantities are sometimes used but the above amounts should be sufficient in most cases.

This form of lime is usually put upon the markets in lumps and before being applied to the soil must be reduced to powder form. This is conveniently done by placing the lime in small piles about the field and covering it with three or four inches of moist soil. The lime will absorb the moisture from the soil and gradually break down into a fine powder, when it may be spread with a shovel.

Ground burned lime may be purchased at a slightly advanced price.

Hydrated Lime.—When burned lime is treated with water or steam it enters into combination with the water and forms what is chemically termed calcium hydrate or hydrated lime. This form, like burned lime, is caustic but it is always in the powder form and may be readily applied to the soil. Fifty-six pounds of burned lime are equivalent to 74 pounds of hydrated lime. This form of lime is also known as slaked (slacked) lime.

Air Slaked Lime.—When burned lime is exposed to the action of the air for any considerable length of time it gradually takes up moisture and carbon dioxide and changes to the hydrate and carbonate forms. If exposed for a sufficiently long time it will all change to the carbonate form or the state in which it was before burning. Its value lies somewhere between that of hydrated lime and ground lime-stone.

Refuse Lime from Sugar Factories.—Burned lime is used in the process of recovering sugar from the sugar beet and this waste lime is partly hydrated and partly carbonated and is consequently very similar to air slaked lime and should be used in about the same amounts. This lime also contains small amounts of nitrogen, phosphoric acid and potash absorbed from the beet juices.

Marl is found quite extensively throughout the state and many of the deposits are very pure calcium carbonate. When the cost of laying down marl on the farm in a dry powder form does not exceed $1.50 per ton it may profitably be used as a substitute for commercial lime.

Leached Hardwood Ashes, contain from 65 to 70 per cent calcium carbonate and under favorable conditions may be used as a substitute for commercial lime. Unleached ashes are more valuable for the potash they contain and should not be used as a source of lime except in cases where this element is also needed.

Burned lime, hydrated lime and air slaked lime are caustic, diminishing in degree, however, in the order named. The fine powder is irritating to the skin and nostrils and its application to the soil is usually attended with more or less discomfort by the persons doing the work. Ground limestone is not caustic and consequently is not irritating to the skin.

When the lime is to be used on heavy clay soils to correct the physical condition, the burned lime or hydrated lime are recommended as these forms act more rapidly than the ground limestone. For use on light sandy soils the ground limestone or marl is recommended.

EQUIVALENT WEIGHTS.

1,000 pounds burned lime is equivalent to:

1,351 pounds hydrated lime.
1,786 pounds ground limestone or marl.
1,351-1,786 pounds air slaked lime.
About 3,000 pounds hardwood ashes.

After several years of careful experimenting upon the use of lime on various soils and with many different crops, Dr. H. J. Wheeler of the Rhode Island Experiment Station has made a classification of plants according to their action with reference to lime.

The following table is based on Wheeler's classification:

Plants benefited by lime.	Plants indifferent to lime.	Plants injured by lime.
Beans. Beets. Celery. Onions. Cabbage. Pea. Alfalfa. Clover. Barley. Wheat. Oats. Timothy. Kentucky Blue Grass. Seed Fruits. Stone Fruits.	Corn. Millet. Golden Rye. Potatoes. Carrots. Red Top Grass.	Watermelon. Blue Lupine. Sheep Sorrel.

In a number of cases in this state lime has been found to be very beneficial for clover and alfalfa.

HOW TO APPLY.

If the lime is being applied for the benefit of any immediate crop, it should be applied, in whatever form used, after the plowing has been done and should then be thoroughly harrowed into the surface soil. It is best to make the application some little time before sowing the crop.

Whatever form of lime is used, if it is in a fine condition, either as the result of grinding or of slaking, the best method of applying it to the soil is by the use of a lime spreader, of which there are a number of kinds on the market. The ordinary fertilizer drill does not spread any of these materials well except the very finely ground limestone.

It is occasionally recommended that lime in whatever form, if in a fine condition, be applied to the soil by hand, much as one would sow grain by hand. In windy weather this method is likely to prove very disagreeable to the sower. At any time unless gloves are used, the lime is very likely to irritate the hands.

A very satisfactory way is to distribute the material in piles two rods apart each way, and then later each pile can be spread with a shovel over an area extending about one rod in all directions from the pile—each pile is spread so as to cover four square rods of area. A fairly even distribution can be made in this way and the distribution is improved when the lime is harrowed into the soil. By this method there will be forty piles to the acre. The amount of material to be put in each pile is found by dividing the rate of application in pounds per acre by forty. If the rate be 800 pounds per acre 20, (800÷40) pounds

is the amount per pile. If the rate be 1,200 pounds per acre 30, (1,200÷40) pounds is the amount per pile.

In applying underground or unslaked burned lime, probably the best way is to distribute in piles as described above and allow to stand until slaked. It will not require a long time for the air to accomplish the slaking. A small amount of water may be applied to each pile, though this might prove something of a task. A few shovelfuls of moist soil thrown upon each pile is said to accomplish the slaking in a very short time. When the slaking has been accomplished the spreading should be done as indicated above.

The manure spreader has been recommended for spreading lime. The method proposed is to load the spreader just full with manure, being careful to level the load evenly. A proper amount of lime is then spread over the top of the load and is thus spread with the manure. Some objection has been offered to this method in windy weather. The amount of lime to be added to each load of manure may be determined by dividing the intended application per acre, by the number of loads of manure which is being applied per acre. If six loads of manure is the rate of application and 900 pounds of lime is to be applied per acre 150, (900÷6) pounds is the weight of lime to be added to each load of manure. If 1,200 pounds is the rate at which the lime is to be applied per acre, then 200, (1,200÷6) pounds of lime is added to each load.

In applying marl it is best to dig the marl, throw into piles, and allow to stand for some days or even weeks before hauling to the field. By some it is recommended that the marl should be dug in winter. This will allow much of the water in the marl at the time of digging to evaporate. The marl should then be hauled to the field and distributed in piles as described above. When air dry, the marl is easily pulverized and distributed. A slanting blow with the back of a shovel will usually reduce a large lump of air dry marl to powder.

As stated above not all soils are benefited by an application of lime. Probably the great majority of Michigan soils will not be benefited by an application of lime. There is only one sure way of determining whether a soil needs lime and that is by trial. An application of lime over a whole field would be a waste of both time and money if the field were not in need of such an application. It is suggested that the farmer who has not already proven for himself whether his soils need lime would better conduct a few simple experiments at different points on his farm. A few barrels of lime or a few tons of limestone or a few loads of marl would not cost a great deal and the labor of treating a strip with lime or ground limestone here and there across different fields in which crops were to be grown or to treat a small area here and there, at different points in fields in which crops are to be grown, would involve but a small amount of labor. These areas should be very carefully located and marked and the results of the applications should be carefully studied on the succeeding crops. It is possible that the effects, good or bad, may be easily apparent. It is possible that there will be no effects and it is possible that the effects can be discovered only by carefully cutting and weighing the crop from portions of the treated areas and comparing them with the crops produced upon equal adjacent areas.

Cautions.—*Lime should not be applied to manure piles nor to the litter in the barn.*

Lime should not be applied to land being prepared for potatoes.

FOREWORD.

Special Bulletin No. 54.

All fruit trees, bushes and vines are attacked by many insects and diseases that may destroy the crop entirely or very seriously lessen its value. *Fruit buyers and dealers do not care to buy or handle fruit from orchards that have not been well sprayed.*

Proper, thorough and systematic spraying will protect the tree or bush and may cause the difference between success and failure in the production of a profitable crop.

This outline aims to give methods of control for the more common insects and diseases only. For pests not included, write to the Department of Entomology or the Department of Horticulture, Michigan Agricultural College, East Lansing, Mich., as the case may be. Or consult special bulletin 24, "Insects Injurious to Fruits in Michigan," and regular bulletin 233, "Insects of the Garden."

GENERAL TREATMENT FOR APPLES.

When to Spray.	*What to Use and What For.*
As late as possible before buds start.	Strong lime-sulphur wash, if San Jose scale is present. This scale must be destroyed or it will ruin the trees. For scurfy-scale use lime-sulphur wash as late as possible before buds swell.
Just before the blossoms open. Fig. 2.	Bordeaux mixture or dilute lime-sulphur solution for scab, leaf-spot diseases and canker, with poison for canker-worm and bud-moth. The experience of some growers indicates that this spraying may be omitted if one has been made with lime-sulphur for San Jose scale, unless canker-worm is present.
Just after the blossoms fall and stamens wither. Fig. 1.	Bordeaux mixture or dilute lime-sulphur solution for the diseases mentioned before with a poison for bud-moth, tussock-moth, codling-moth and other insects. This and the last are the most important single sprayings. Do not neglect them.
Ten days to 2 weeks after the previous spraying.	Same mixture for diseases and insects mentioned above.
First week in August.	Bordeaux mixture, not full strength, or dilute lime-sulphur solution, and poison, full strength, for the second generation of codling-moths, except on summer varieties. This is an important spraying, especially for late fall and winter varieties. See "When the Coddling-Moth Flies" on later page. The lesser apple-worm, when present, requires a spray of poison when standard winter varieties are from 1 to 1½ inches in diameter. A diluted solution of the boiled lime-sulphur wash has come into considerable use during the past few years as a substitute for the Bordeaux mixture for spraying apples. See later page.

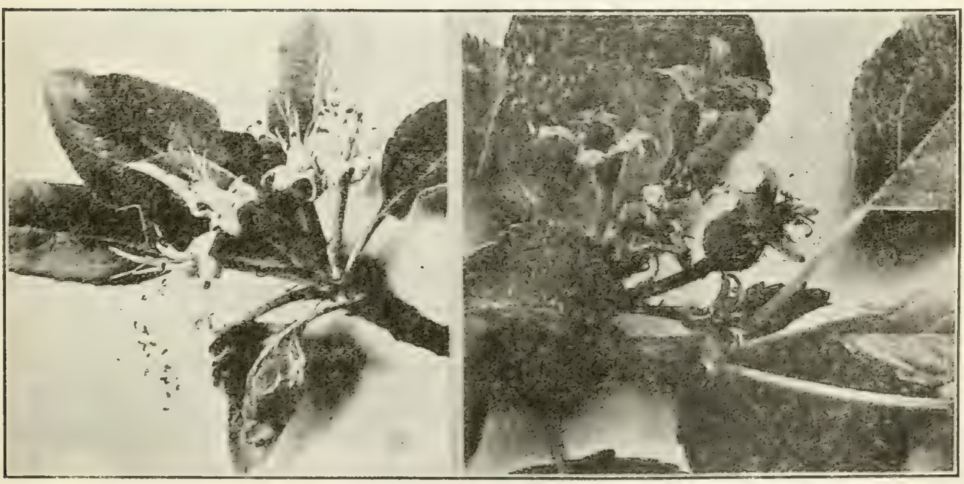


Fig. 1.

Too early. Just right.

Fig. 2.

GENERAL TREATMENT FOR PEACHES.*

When to Spray.	*What to Use and What For.*
Early in the spring, surely before the buds swell.	Strong lime-sulphur wash for San Jose scale, if present. This spraying will also answer for the leaf-curl. If San Jose scale is not present, Bordeaux mixture for the leaf curl.

FOR ORCHARDS AFFECTED WITH THE BROWN ROT, SCAB, AND CURCULIO.

When to Spray.	*What to Use and What For.*
1st time.	About the time the shucks are shedding, spray with arsenate of lead at rate of 2 pounds to 50 gallons of water.
2nd time.	Two to three weeks later or about one month after the petals drop, spray with 8-8-50 self-boiled lime-sulphur and 2 pounds arsenate of lead.
3rd time.	About one month before the fruit ripens, repeat the above spraying, omitting the poison.

For early varieties the first two sprayings will probably be sufficient, unless the season is very wet and the varieties very susceptible to rot.

*This line of treatment and the preparation of the self-boiled lime-sulphur mixture are based upon the recent successful experiments of the Bureau of Plant Industry of the Department of Agriculture.

FOR BROWN ROT AND SCAB, WHERE THE CURCULIO IS NOT TROUBLESOME.

When to Spray.	*What to Use and What For.*
1st time.	Two or three weeks after the petals fall, with 8-8-50 self-boiled lime-sulphur.
2nd time.	About three weeks later, repeat previous spraying.
3rd time.	About one month before fruit is expected to ripen, repeat previous spraying.

FOR SCAB ONLY.

When to Spray.	*What to Use and What For.*
	About one month after petals fall, spray with 8-8-50 self-boiled lime-sulphur and again three or four weeks later.
	In applying the self-boiled lime-sulphur mixture, special care must be taken to keep it well agitated. The mixture settles rapidly and unless well agitated it will not be evenly sprayed. With the last spraying use fine nozzles and give the trees a uniform coating of a mist-like spray

GENERAL TREATMENT FOR PEARS.

When to Spray.	*What to Use and What For.*
Same as for apple.	Strong lime-sulphur for San Jose scale, blister-mite and pear-psylla, if present. For scurfy-scale use lime-sulphur as late as possible before buds open. Bordeaux mixture with poison as directed for the apple.
Pear blight.	Whenever a blighted branch is found, cut back to sound wood and burn. Systematic inspections made during fall, winter, and early spring, a short time before blossoms open, to remove all "winter hold-over" cases, is very beneficial. After each branch is cut, disinfect tool by wiping with a cloth or sponge moistened with 5% carbolic acid.
	If "slugs" appear, spray with an arsenical, if not too near ripening of fruit to be dangerous. In case of early pears, dust with fresh hydrated lime.

GENERAL TREATMENT FOR PLUMS.

When to Spray.	*What to Use and What For.*
Early in the spring before growth starts.	Strong lime-sulphur wash for San Jose scale or European fruit-scale, if present, the same as for apple.
Just before buds swell.	Bordeaux mixture or self-boiled lime-sulphur mixture for fruit-rot, leaf-spot, and black-knot, with arsenate of lead for curculio.

Immediately after the blossoms fall.	Bordeaux mixture or self-boiled lime-sulphur mixture for fruit-rot and leaf-spot with arsenate of lead for curculio. (For the Japanese varieties, dilute the Bordeaux about one-half, or use self-boiled lime-sulphur mixture.)
Ten days or two weeks later.	Repeating the previous sprayings will tend to check the fruit-rot and curculio. This spraying should be repeated every 10 days or 2 weeks until there is danger of staining the fruit; stopping at least a month before picking time. On varieties especially susceptible to rot, an application of weak copper sulphate may be made about 2 weeks before ripening. No poison should be added. One pound copper sulphate to 150-200 gallons of water.
	Black knot.—At the annual pruning, cut out all knots. A careful inspection should be made in the early spring, and all knots cut out and burned. Cut back several inches below the knot. Wild cherry trees harbor the trouble and if near plum or cherry orchards, should be removed, if possible.

GENERAL TREATMENT FOR CHERRIES.

When to Spray.	*What to Use and What For.*
Early in the spring before growth starts.	Strong lime-sulphur wash, if San Jose scale is present. The same as for apple trees.
Just before the blossoms open.	Bordeaux mixture or self-boiled lime-sulphur mixture for fruit rot and leaf-spot. This is especially valuable on English Morellos for leaf-spot.
Just after the blossoms fall.	Bordeaux mixture or self-boiled lime-sulphur mixture for fruit-rot and leaf-spot, with arsenate of lead for curculio and slug.
Ten days to 2 weeks later.	Bordeaux mixture or self-boiled lime-sulphur mixture for fruit-rot and leaf-spot. This spraying may not be necessary, depending upon the susceptibility of the variety to fruit-rot and the weather conditions of the season.
	The large, black lice may be killed with tobacco water, if it is applied before the leaves curl too tightly.
	If slugs appear after picking, spray with arsenate of lead.

GENERAL TREATMENT FOR GRAPES.

When to Spray.	*What to Use and What For.*
When the shoots are about 8 to 10 inches long.	Bordeaux mixture for black-rot.
Just before blooming.	Bordeaux mixture for black-rot, with poison for the grape-berry moth and rose-chafer.
Just as the blossoms fall.	Same as before.
About 10 days or 2 weeks later.	Bordeaux mixture and poison for black-rot and berry-moth. The need for this spraying depends upon the weather conditions and the amount of rot prevalent in the vineyard. If it is thought advisable to make later sprayings, some material should be used that will not stain the fruit.
	In vineyards where flea-beetles appear, Bordeaux and a strong arsenical poison just before the buds burst.
	In vineyards where the grape-berry moth is serious, spray with Bordeaux and an arsenical poison during the middle of July, before the 20th.
	For leaf-hoppers (sometimes, but incorrectly, called "thrip") tobacco-water or kerosene-emulsion while the insects are young. (Burning rubbish late in the fall will destroy many hibernating leaf-hoppers.)

GENERAL TREATMENT FOR CURRANTS AND GOOSEBERRIES.

When to Spray.	*What to Use and What For.*
Before growth starts.	Lime-sulphur wash for San Jose scale or European fruit scale, if present. Cut out and burn wilted and hollow canes containing borers.
Just as the leaves are expanding, if worms appear.	Bordeaux mixture and poison, ¼ pound of Paris green or 2 pounds of arsenate of lead, to 50 gallons. Repeat if worms reappear before fruit is ¼ grown, if later, then use pyrethrum or hellebore.
	If leaf-bugs or aphids appear, spray with tobacco-water or kerosene-emulsion while the bugs are red and wingless, and before leaves become curled.
	Gooseberry-mildew. Where this disease is known to be serious, begin from the time the buds start and spray with potassium-sulphide, 1 oz. to 2 gallons of water, and repeat about every 10 days.

GENERAL TREATMENT FOR RASPBERRIES, BLACKBERRIES AND DEWBERRIES.

When to Spray.	*What to Use and What For.*
Orange rust, determined by the bright, orange color on the under side of the leaves.	No method of preventing. Dig the plant as soon as discovered and burn.
Anthracnose, grayish spots on the canes and leaves.	Cut out and burn all canes after fruiting. Spraying may check the disease, but may not be profitable. If desirable, make first spraying when new canes are 6 to 8 inches high, and repeat twice about 2 weeks apart. Do not set diseased young plants.
	Cut cut and burn borers in stem, gouty galls, and tree-cricket eggs.
"Worms" or "slugs."	Spray with an arsenical if fruit is just set, later use hellebore or pyrethrum.

GENERAL TREATMENT FOR STRAWBERRIES.

When to Spray.	*What to Use and What For.*
Young plantations.	Before setting the young plants, pick off all diseased leaves and if root-lice are suspected, dip in strong tobacco-water. After growth starts spray with Bordeaux, for leaf-spot and poison for leaf-curl, if present.
Fruiting plantations.	Spray with Bordeaux before blossoming and repeat 10 days or 2 weeks later. After fruiting, mow and burn over, if plantation is to be fruited again. If leaf-rollers have been present, spray with an arsenical after growth has started again, but before leaves curl. For strawberry root-lice, see bulletin 244, page 88.

GENERAL TREATMENT FOR POTATOES.

When to Spray.	*What to Use and What For.*
For scab.	Soak the uncut tubers for two hours in 30 gallons of water and one pint of formalin (can be secured of any druggist). This solution can be used several times. Do not put treated tubers back into crates or bags that held scabby potatoes. Make the treatment only a few days before planting if possible. Do not plant upon land that has recently grown crops of scabby potatoes or beets.

When large quantities of potatoes are to be treated, formaldehyde gas may be used to advantage as follows: * "Place seed tubers in bushel crates or shallow slat-work bins in a tight room. For each 1,000 cu. ft. of air space in the room, spread 23 ounces of potassium permanganate evenly over the bottom of a large, flaring pan or pail placed in the middle of the room. Pour over this three pints of formalin. Close room at once and do not open for 24 or 48 hours."

For blight and "bugs."

Begin spraying with Bordeaux mixture and poison when the "bugs" first appear, or when the plants are about 8 inches high, and repeat about every 2 weeks as long as the plants are growing. Spray often in warm, muggy weather; it is not as necessary in dry weather.

Use Bordeaux mixture (6 pounds copper sulphate and 4 or 5 pounds of lime to 50 gallons of water, and put in the poison, about ½ pound of Paris green or 2 pounds of arsenate of lead, or 1 quart of the stock solution of Kedzie mixture.

PREPARATIONS OF SPRAY MIXTURES.

FUNGICIDES.

DILUTE BOILED LIME SULPHUR SOLUTIONS FOR SUMMER SPRAYING OF APPLES.

During the past seasons, tests have been made to determine the comparative value of dilute solutions of boiled lime-sulfur and Bordeaux mixtures for spraying apple orchards.

The advantages of the dilute lime-sulphur solutions over bordeaux mixture were found to be:

(a) That the fruit was not russetted as badly. This was especially so with Wagener, R. I. Greening, Baldwin, Ben Davis and Hubbardston.

(b) Ease with which the solution was prepared—where a commercial concentrated brand was used.

(c) Very slight wear on the pump and packing and no trouble with nozzle clogging, since the solution did not contain any grit, as Bordeaux mixture does.

(d) Appeared to lessen the number of San Jose scales.

Encouraging as the results have been from the use of the diluted lime-sulphur solution, it must be remembered that it has not been compared with Bordeaux mixture in Michigan in a season when the apple scab fungus has been serious, and until this has been done, its use must be considered in the experimental stage and Bordeaux not entirely abandoned.

The diluted lime-sulphur solution can be prepared for use in several ways.

1st. Commercial concentrated lime-sulphur solution can be diluted

*From Bul. 149, Maine Exp. Sta.

and used. Test with a Baumé hydrometer (see later page) and dilute as follows:[1]

If test is	
33°, 32°, 31°	Baumé dilute $1\frac{1}{2}$ gallons to 50 of water.
30°, 29°, 28°	Baumé dilute $1\frac{3}{4}$ gallons to 50 of water.
27°, 26°, 25°	Baumé dilute 2 gallons to 50 of water.
24°, 23°, 22°	Baumé dilute $2\frac{1}{4}$ gallons to 50 of water.

2nd. Use home-made concentrated lime-sulphur solution (See later page). Test each lot with the Baumé hydrometer and for use, dilute as directed for the commercial concentrated solution.

3rd. To make the dilute solution at any time and in any quantity; Boil in a few gallons of water for one hour, *twice* as many pounds of sulphur as of lime, strain and dilute with water so there will be 8 pounds of sulphur to every 100 gallons.

Example: To make 100 gallons of spray solution, boil 8 pounds of sulphur and 4 pounds of lime as directed.

Poison to Use in Lime-Sulphur Sprays.

The only poison that should be used in the lime-sulphur sprays is arsenate of lead. Work this into a thin paste and *do not add to the lime-sulphur solution until just before ready to begin spraying.*

SELF-BOILED LIME-SULPHUR MIXTURE.

This mixture has come into prominence in the past few years and its chief value is that it does not (when properly made) injure peach or plum foliage.

The formula is:

Lump lime	8 pounds
Sulphur	8 pounds.
Water	50 gallons.

The mixture can be prepared better by using thirty-two pounds of lime, thirty-two pounds of sulphur, and eight or ten gallons of water, and then diluting to 200 gallons.

Place the lime in a barrel and add enough water to almost cover it, as soon as the slaking begins, add the sulphur, which should be run through a sieve to break up the lumps.

Stir constantly and add enough water to make a thick paste and then, gradually, a thin paste. As soon as the lime is well slaked, cold water should be added to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted up to the full formula, and used.

Care must be taken not to allow the boiling to proceed too far, if the

[1]Circular 10 Mich. Agr. Exp. Station.

mixture remains hot for fifteen or twenty minutes after the slaking is completed, some sulphur will go into solution and injury to the foliage may result.

The time of adding the cold water to stop the boiling depends upon the lime. With a sluggish lime all the heat in it may be needed, while with limes that become intensely hot, care must be taken not to allow the boiling to proceed too far.

BORDEAUX MIXTURE.

Bordeaux mixture is the standard spraying mixture used to protect plants from such fungous diseases as apple and pear scab, grape-rot, leaf spots, mildews, potato blight, etc. There are but three things used in its preparation,—water, lime and copper sulphate. The water acts as a carrier, the lime neutralizes the caustic action of the copper sulphate and also makes the mixture stick to whatever it is sprayed upon, and the copper sulphate is the chemical that prevents the growth of the spore of the disease.

These three substances are combined in various proportions, depending upon the kind of plant to be treated. For apples, pears, cherries and plums (except the Japanese varieties) the preparation is usually four pounds of copper sulphate, with about the same amount of lime, to fifty gallons of water. Poison is added as needed. The copper sulphate will readily dissolve in two gallons of hot water, to which should be added enough water to make twenty-five gallons or one-half barrel. Do not use an iron or tin vessel to dissolve this in, as the copper sulphate will destroy it, and besides the iron will spoil the Bordeaux. A wooden pail is good. Slake the lime into a thin paste and add water to make twenty-five gallons. Pour, or let these run together into a third barrel, and the Bordeaux is made. When it is emptied into the spray barrel or tank, it should be strained through a brass wire strainer to catch any of the coarse particles.

Whenever it is necessary to use a quantity of the mixture, it is desirable to have the lime and the copper sulphate in "stock solutions." A quantity of lime is slaked to a paste and held so by being covered with water. The copper sulphate, say fifty pounds, is placed in a clean gunny sack and suspended in a barrel (one with wood hoops is much to be preferred) containing twenty-five gallons of water. This will dissolve in about a day. One gallon of this "stock solution"* is equal to two pounds of copper sulphate.

A good quick way to combine these three substances is as follows: Put the amount of the "stock solution" of copper sulphate required in a barrel, and add enough water to make 25 gallons, or one-half barrel. Put about 7 pounds of the lime paste in a barrel and add 25 gallons of water, making a thin whitewash. Pour, or let these two run together into a third barrel, or directly into the spray barrel or tank, being sure to strain. When partly run in, test with ferro-cyanide of potash† to

*Always stir this "stock solution" before dipping any out, in order that what is used may be full strength.

†This chemical can be secured of any druggist. Ten cents worth dissolved in a pint of water will be enough for a season. Drop a very little in the bordeaux, if a reddish brown color appears more lime must be added. If there is no discoloration, there is enough lime.

make sure enough lime has been used. If Paris green, arsenate of lead, or any other poison is to be used, make it into a thin paste with a little water and add it to the Bordeaux mixture, which is now ready to be used.

INSECTICIDES.

POISONS, FOR INSECTS THAT CHEW.

PARIS GREEN AND LIME.

Always use lime with Paris green, it makes the poison stick better, beside greatly reducing the danger of burning the foliage.

For spraying from a barrel, the writer has found the following method very useful,—Place from one-quarter to one-half pound of good lump lime, or unslaked lime, in each of three or four tin pails which will hold about three quarts or less. Old cans or crocks will answer just as well. Add enough hot water to slake it into a thin cream or paste. Now add to each lot, one-quarter pound of Paris green, previously weighed out, and placed in paper bags, stir while the lime is hot and allow to stand for some time. Now measure out about forty-four gallons of water in your spraying barrel, and make a mark that will show how high it comes in the barrel, add the contents of one tin pail (viz., one-quarter of a pound of Paris green and one-half pound of quick-lime slaked) into the forty-four gallons of water in the barrel. Stir well and spray. The pails or crocks can be used one at a time and refilled occasionally so that the stock is always on hand ready for use.

KEDZIE MIXTURE (ARSENICAL).

This mixture, originated by the late Dr. R. C. Kedzie, of this station, is cheap, but it has the disadvantage of lacking a warning color. It is a good substitute for Paris green, but must be made with care, and stored in well labeled jugs.

Dr. Kedzie in giving directions for its preparation says: "Dissolve the arsenic by boiling with carbonate of soda, and thus insure complete solution; which solution can be kept ready to make a spraying solution whenever needed. To make the material for eight hundred gallons (800) of spraying mixture, boil two pounds of white arsenic with eight (8) pounds of sal soda (crystals of carbonate of soda—'washing soda'—found in every grocery and drug shop) in two gallons of water. Boil these materials in any iron pot not used for other purposes. Boil for fifteen minutes or until the arsenic dissolves, leaving only a small muddy sediment. Put this solution into a two-gallon jug, cork tightly, and label 'Poison,' stock material for spraying mixture."

"The spraying mixture can be prepared whenever required, and in the quantity needed at the time by slaking two pounds of lime, adding this to forty gallons of water; pour into this a pint of the stock arsenic solution. Mix by stiring thoroughly and the spraying mixture is ready

for use. The arsenic in this mixture is equivalent to four ounces of Paris green."

"The pot, jug, etc., must never be used for any other purpose after using it for making this mixture."

"If an additional pound or two of lime be added to the mixture, it will help to make the application permanent and conspicuous without in any way interfering with its effects. In using it the extra lime should be added."

ARSENATE OF LEAD.

This poison is coming into general use throughout the country, and has several advantages; it shows where it has been applied; and it does not easily burn the foliage.

Its action is slower than that of Paris green, but the fact that it does not readily burn the foliage is an advantage when spraying various kinds of delicate trees with one mixture. It is used at the rate of from one to five pounds to fifty gallons of water or Bordeaux—or the lime sulphur sprays.

CONTACT INSECTICIDES, FOR INSECTS THAT SUCK.

KEROSENE EMULSION.

Place two gallons of ordinary kerosene in a warm place, either in a warm room or in the sun, and allow to become as warm as possible without danger from fire. Boil one pound of laundry soap or whale-oil soap in a gallon of soft water until completely dissolved. Remove the soap solution from the fire, and while still boiling hot, add the kerosene and agitate vigorously for ten minutes, or until the oil is emulsified, with a spraying pump by forcing the liquid back into the vessel from which it was pumped. When the liquid is perfectly emulsified it will appear creamy in color and will flow evenly down the side of the vessel when allowed to do so. Care should be taken to completely emulsify the oil and this is accomplished much more easily when the mixture is hot. This strong emulsion may now be readily diluted with water and used, or it may be stored away for future use. When cold it becomes like sour milk in appearance and should be dissolved in three or four times its bulk of hot water before diluting with cold water. If the water is at all hard, "break" it by adding a little sal-soda before putting in the soap.

Small amounts of this emulsion may be made by using the ingredients in small quantities but in the same relative proportion. It is used at the rate of eight or ten parts of water to one part of emulsion.

STRONG LIME-SULPHUR FOR DORMANT TREES AND SHRUBS.

This is a contact insecticide which should be used preferably just before growth starts, in any case, before the buds swell in the spring. If used when foliage is on the trees, the foliage will be killed. It is made in several ways, one of which is as follows:

Lump lime	20 pounds.
Sulphur (flour)	15 pounds.
Water (hot) to make	50 gallons.

The lime is slaked with a small amount of hot water and the sulphur is sifted in, fifteen or twenty gallons of hot water is then added, and the mixture boiled. (It should take three-quarters of an hour or an hour of good boiling with frequent stirring.) When done the liquid should be amber colored and fairly clear. Strain, dilute with hot water to make (up to) 50 gallons, and apply warm, through a coarse nozzle.

If small quantities are required, use an iron kettle to boil it in. If larger quantities are to be used, live steam is preferable for boiling purposes, either in a tank or in barrels.

Applied just before the buds swell, it coats the branches in such a way as partially to hinder from settling down, such pests as the oystershell, scurfy scale, some aphids, and others.

HOME-MADE CONCENTRATED LIME-SULPHUR WASH.

The advantages in using the home-made concentrated lime-sulphur wash, are that a quantity of it can be cooked in advance and often at times when the actual work of spraying is not pressing. The great disadvantage about it is that every lot cooked has to be tested with a hydrometer, to determine its strength, and then diluted accordingly. Several Experiment Stations, especially Pennsylvania[1] and New York,[2] have made experiments with various ways of preparing this concentrated wash but as yet no definite way has been found to make it of uniform strength, or composition. Investigations have been made by the Chemical Division of the Michigan Experiment Station in regard to the manufacture and storage of the lime-sulphur wash and will be published in circular No. 10. The difficulty of getting a wash of uniform strength, apparently lies with the lime, which varies in composition and strength. Lime that contains more than five per cent of magnesium oxide and less than 90 per cent of calcium oxide does not combine in the cooking with the sulphur in a way to make a good mixture.

Lump lime	60 pounds.
Sulphur	125 pounds.
Water	50 gallons.

The lime is slaked to a thin paste and the sulphur is sifted in. Boil for one hour and stir frequently. Water enough should be added so that there will be fifty gallons at the end of the boiling.

After it is cooked, if not to be used at once, it should be strained into a barrel which should be air tight, as exposure to the air causes the sulphur compounds to lose their value for spraying purposes. Each lot that is cooked should be tested with a hydrometer when cooled and diluted according to the following table when applied:

[1]Stewart, J. P., Penn. Station, Bulletin 92.
[2]Parrott, P. J., New York Station, Bulletin 320.

Concentrated Lime Sulphur Solution Diluted to Spray for San Jose Scale.

If Baumé test is 33° dilute 6-¼ gallons to 50 gallons.
If Baumé test is 32° dilute 6-½ gallons to 50 gallons.
If Baumé test is 31° dilute 6-¾ gallons to 50 gallons.
If Baumé test is 30° dilute 7 gallons to 50 gallons.
If Baumé test is 29° dilute 7-½ gallons to 50 gallons.
If Baumé test is 28° dilute 7-¾ gallons to 50 gallons.
If Baumé test is 27° dilute 8-¼ gallons to 50 gallons.
If Baumé test is 26° dilute 8-¾ gallons to 50 gallons.
If Baumé test is 25° dilute 9 gallons to 50 gallons.
If Baumé test is 24° dilute 9-½ gallons to 50 gallons.
If Baumé test is 23° dilute 9-¾ gallons to 50 gallons.
If Baumé test is 22° dilute 10 gallons to 50 gallons.
If Baumé test is 21° dilute 10-½ gallons to 50 gallons.
If Baumé test is 20° dilute 10-¾ gallons to 50 gallons.
If Baumé test is 19° dilute 11-¼ gallons to 50 gallons.
If Baumé test is 18° dilute 11-½ gallons to 50 gallons.
If Baumé test is 17° dilute 12 gallons to 50 gallons.

THE BAUME HYDROMETER.

The hydrometer is an instrument used to determine the weight and density of liquids. It is made of glass, is about one foot long, with a graduated scale on the side. It can be purchased from wholesale dealers in druggists' supplies, from Bausch & Lomb Optical Co., of Rochester, N. Y., or Whitall Tatum Co., Philadelphia, Pa. Directions for use should come with the instrument.

COMMERCIAL CONCENTRATED LIME-SULPHUR WASH.

There are several brands of commercial, concentrated preparations of lime-sulphur wash on the market. They are now reasonable in price and when a limited amount of spraying is to be done it may be desirable to purchase one rather than to go to the trouble of preparing a small quanty at home.

HELLEBORE.

White hellebore is the powdered root of a plant. It kills both by contact and as an internal poison. It may be applied either dry or in the form of a liquid. When used dry it should be mixed with three or four times its weight of flour or of plaster and then dusted on the insects. Applied wet, one pound should be mixed with twenty-five gallons of water and this liquid applied as a spray.

INSECT POWDER, BUHACH, PYRETHRUM.

This valuable remedy has one drawback, its cost. It is too expensive for use on a large scale. It kills insects through their breathing pores,

but is harmless to man and beast. It will kill many of the insects of the garden if dusted on or applied as a spray at the rate of one ounce to two gallons of water.

Use the powder when it is undesirable to use poison, but never buy any unless it comes in tightly sealed packages. It loses its strength on short exposure to the air. An hour will suffice to weaken it. It must be applied from time to time, as it quickly loses its strength.

TOBACCO.

Tobacco in the form of dust may be obtained of the large manufacturers at a few cents a pound.

It is useful in destroying root-lice, especially woolly-aphis, in young trees, and in keeping insects from garden truck. For root-aphis, incorporate four to six handfulls of tobacco dust into the soil about the roots and induce a thrifty, healthy growth by using liberal quantities of nitrate of soda or barnyard manure early in the spring.

A strong infusion or tea made of waste will kill plant lice if sprayed when they first appear.

HYDRATED LIME.

Finely slaked lime is often useful because of its slight caustic properties. Against such larvae of saw-flies and beetles as are sticky, for instance those of the cherry-slug and asparagus-beetle, it may be used as a substitute for poison, if the latter, for some reason is undesirable.

Stone lime may be slaked with a small amount of hot water, using just enough to turn it to a dry powder. Such slaked lime is as fine as flour and very soft to the touch, having very little grit. Use a metal pail or kettle to slake in, as the heat may set fire to wood. Do not use too much water, and where possible, use freshly burned lime.

Hydrated lime may be used in making Bordeaux mixture, but it is not as reliable as good, fresh, lump lime. It is less adhesive, not as strong (so more should be used) and more expensive. The one advantage is that it is a little easier to use.

Ground lime for making Bordeaux mixture acts exactly like lump lime, if fresh, but this is difficult to determine as it is already in a powder.

CAUTIONS.

Do not spray while plants are in bloom. It is prohibited by law, except when canker-worm is present, and may destroy bees and other beneficial insects.

Do not dissolve copper sulphate in an iron or tin vessel. It will ruin the vessel and spoil the spraying solution.

For all spraying solutions containing copper sulphate, the pump must be brass or porcelain lined.

Wash out pump and entire outfit each time after using.

Use arsenate of lead on stone fruits in preference to other forms of arsenical poisons. It is less liable to burn the foliage.

Do not spray fruits or plants with poison within a month or more of the time when they are to be picked.

Keep all "stock solutions" covered to prevent evaporation.

WHEN THE CODLING-MOTH FLIES.

While the first week in August is a good average time for applying an arsenical spray for the second generation of the Codling-moth in Michigan, it is well to remember that seasons vary, and that the time set aims merely at an average. To determine exactly each year just when to get the highest efficiency out of a spray, for a particular locality, requires only a few hours of work, providing one can find some neglected apple trees near at hand.

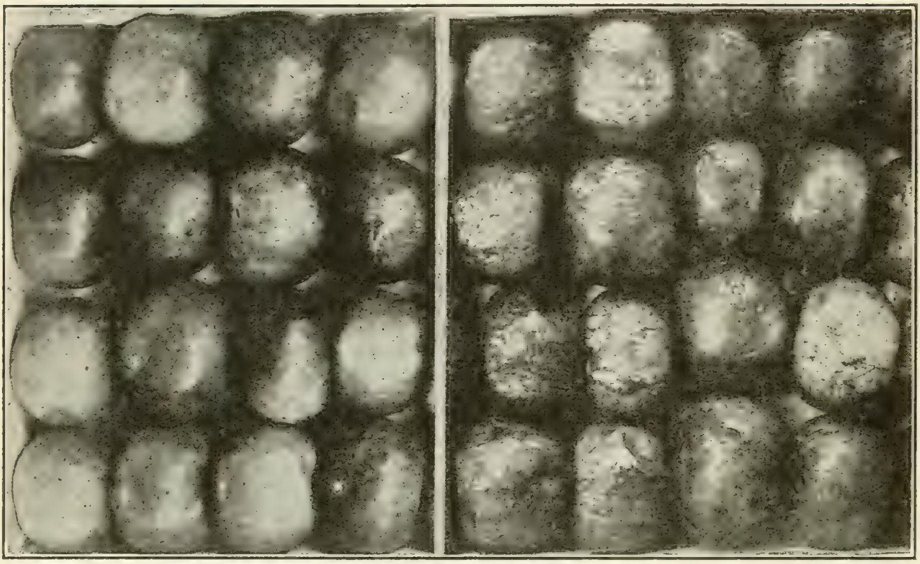
First of all scrape off all loose bark-flakes from the trunk and limbs of several trees, thus destroying all the natural places for the hiding away of the cocoons. The scraping is most easily done while the bark is soft after a prolonged rain.

Next, make some bands of burlaps six or eight inches broad and three or four layers thick; place one around the trunk of each prepared tree and fasten with a headless wire nail driven into the tree so that the band can easily be removed. Do this in June so that the cloth may become weathered before the time for spinning up. The larvae in searching for a good place to spin cocoons will find the bands, in the absence of other protection, and spin cocoons there.

Occasionally examinations during July will reveal these cocoons which should be carefully removed by cutting out a small bit of the cloth to which each is fastened.

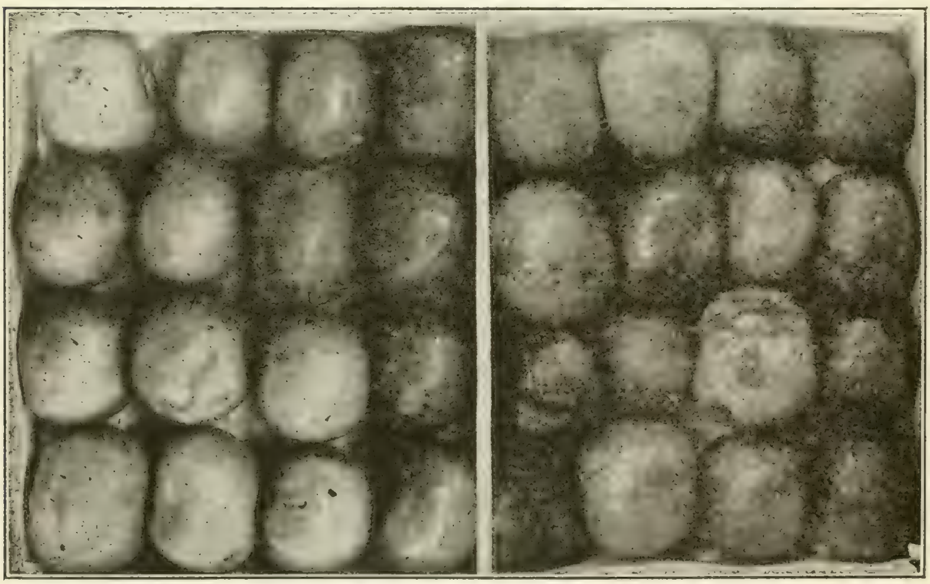
Place all these bits of cloth with the cocoons attached in a cage made of a lantern globe or some other glass cylinder open at top and bottom, and then tie a bit of mosquito netting over the top to confine the insects when they come out of the cocoons. If the lantern globe is set on a little soil in a flower pot and the soil is kept just slightly moist, the chances of getting the moths out are increased.

Now put the cage thus prepared in a shady place where the sun cannot strike it to sweat it, and where the rain cannot penetrate. Outside of protection from rain and sun the conditions should be as near those of the outside as possible. Keep the soil in the pot just moist and look for the moths often during late July for they will hide down under the layers of burlaps and may be overlooked. When you see them in the cage, then you know that they are laying eggs in the orchard and the time to spray is just before the young hatch and go into the fruit, not afterward. Of course they do not come out all together but string along over quite a period.



VARIETY WAGENER.

Sprayed with Lime-Sulphur. Sprayed with Bordeaux Mixture.



VARIETY R. I. GREENING.

Sprayed with Lime-Sulphur. Sprayed with Bordeaux Mixture.

MISCELLANEOUS ANALYSES.

Special Bulletin No. 55.

ANDREW J. PATTEN.

During the past six years a large number of analyses of materials have been made for individual farmers throughout the state. Many of these results are of considerable interest and it is believed that the analyses of some of the samples have never before been reported. It has, therefore, seemed advisable, at this time, to bring these results together and publish them for reference.

I. FEEDING STUFFS.

A great variety of feeding-stuff materials have been sent to the laboratory. Many of them are well known mill-feeds or commercial mixtures, others are not commonly known. The wide variation in the protein content of cottonseed meal indicates that many different grades of this material are being shipped into the state and buyers should be very careful in purchasing this feed-stuff.

Analyses of Feeding Stuff Materials.

Lab. No.	Name.	Moisture, percent.	Protein, percent.	Fat, percent.	Crude fiber, percent.	Nitrogen free extract, percent.	Ash, percent.
2259	Alfalfa meal	15.05	15.25	2.08	25.03	34.13	8.46
1922	Ajax flakes	6.21	31.67	12.67	11.17	....	....
1062	Barley bran	5.91	6.37	3.50	21.65	56.77	5.80
2579	Barley bran	7.88	12.22	3.48	14.75	56.03	5.64
2634	Apple pomace	78.40	1.21	1.96	4.60	12.32	1.51
1939	Beans (red kidney, refuse)	8.37	25.83	1.67	....	....	3.85
1964	Beetseed meal	7.95	11.34	6.22	39.92	28.85	5.72
2268	Brewer's grains	....	29.06	12.62	12.85	....	....
2658	Brewery mash	3.30	20.34	3.11	17.17	52.42	3.66
1589	Buckwheat bran	6.50	10.75	2.88	29.50	47.35	3.02
2271	Buckwheat bran	....	25.50	3.20	34.24	....	....
2251	Buckwheat flour	17.37	5.94	1.39	0.37	74.25	0.68
1591	Buckwheat flour	12.70	8.75	2.45	0.50	74.50	1.10
2635	Buckwheat flour	8.95	9.79	2.25	0.04	77.58	1.39
2580	Cereal feeding stuff	6.88	11.12	2.76	13.75	59.86	5.63

Analyses of Feeding Stuff Materials.—Continued.

Lab. No.	Name.	Moisture, percent.	Protein, percent.	Fat, percent.	Crude fiber, percent.	Nitrogen free extract, percent.	Ash, percent.
1956	Cottonseed meal (cuddo)	4.10	13.30	3.67	32.15	43.18	6.70
1966	Cottonseed meal	10.52	22.62	5.07	20.60	36.67	4.52
2246	Cottonseed meal	8.30	21.00	5.07	22.59	38.69	4.35
2270	Cottonseed meal	....	38.44	9.14	12.48	....	....
2269	Cottonseed meal	....	38.58	7.69	13.25	....	....
2267	Cottonseed meal	....	38.75	9.03	7.96	....	....
2265	Cottonseed meal	....	39.80	5.47	....	....	....
2279	Cottonseed meal	....	40.35	7.79	10.51	....	....
2283	Cottonseed meal	....	40.92	....	....	....	....
2282	Cottonseed meal	....	43.31	8.17	....	....	....
2278	Cottonseed meal (Owl brand)	....	44.52	9.50	9.28	....	....
2647	Cottonseed meal	....	38.99	8.14	11.51	....	....
2657	Cottonseed meal	....	42.75	7.83	11.08	....	....
2626	Cottonseed meal (dark)	6.23	18.75	13.73	22.12	35.05	4.12
2627	Cottonseed meal (light)	6.17	24.33	12.13	17.38	35.42	4.57
1967	Continental gluten feed	10.32	29.69	8.42	5.90	41.08	4.59
1060	Crystal malt flakes	11.30	9.25	5.77	2.76	68.92	2.00
1934	Linseed meal	8.13	30.72	1.45	14.82	38.18	6.70
2280	Linseed meal	....	43.44	2.71	9.71	....	....
1588	Maple flake feed	4.64	13.75	5.37	....	....	3.75
2227	Middlings	11.35	16.62	4.29	4.93	48.57	4.26
1643	Molasses grains (Muellers)	10.19	17.53	3.72	9.47	50.05	9.04
2277	Pea bran	....	19.50	2.43	31.02	....	....
2260	Pea vine hay	14.87	15.56	2.09	25.91	34.79	6.78
1937	Refuse breakfast food	4.78	8.08	0.78	0.35	83.31	2.70
1936	Refuse breakfast food	11.30	6.60	0.28	0.40	78.85	2.57
1644	Sucrene dairy feed	17.71	18.23	5.63	11.15	48.88	8.40
1968	Sucrene dairy feed	11.30	19.00	4.70	11.05	46.33	7.62
1975	Unicorn dairy ration	7.47	29.97	4.80	8.50	47.56	3.70

The sample of Sucrene Dairy Feed No. 1968 was found to contain the following weed seeds: Lamb's quarter, Common Pigweed, Cow Cress, Lady's Thumb, Common Mustard, Black Bindweed, Green Foxtail.

II. SALVAGE WHEAT AND CORN.

Large quantities of salvage wheat and corn are offered for sale for feeding purposes and several samples have been forwarded to the laboratory for analysis. The results of our analyses indicate that, with wheat at least, the feeding value is not perceptibly diminished. In many cases the salvage grains contain considerable quantities of charcoal and wood-

ashes which should be taken into account when purchasing these damaged grains.

Analyses of Salvage Wheat.

Lab. No.	Name.	Moisture, percent.	Protein, percent.	Fat, percent.
2262	Salvage wheat	....	11.00	2.77
1953	Salvage wheat	....	12.12	....
1954	Salvage wheat	....	13.56	....
1960	Salvage wheat	....	14.49	....
1959	Salvage wheat	....	14.43	....
1958	Salvage wheat	....	13.81	....
1930	Salvage wheat	8.05	14.22	1.14
1916	Salvage wheat	....	11.88	1.98
1926	Salvage wheat	7.21	10.90	....
1925	Salvage wheat	8.55	11.90	....
	Average	7.94	12.83	1.96
	Average analysis of 310 samples of undamaged wheat	10.50	11.90	2.10

Analysis of Salvage Corn.

Lab. No.	Name.	Moisture, percent.	Protein, percent.	Fat, percent.	Ash, percent.
1935	Salvage corn	10.01	8.63	1.88	1.55

Corn is evidently damaged more by fire than wheat, as the average analysis of 208 samples of corn gives 10.5% protein and 5.4% fat.

III. PROTEIN IN ALFALFA STEMS AND LEAVES.

The samples were submitted by the division of Farm Crops.

Analyses of Alfalfa stems and leaves.

Lab. No.	Name.	Protein, percent.	Ash. percent.
1656	Alfalfa stems, 1908	11.72	6.80
1970	Alfalfa stems, 1909	15.86	....
1655	Alfalfa leaves, 1908	20.31	9.10
1971	Alfalfa leaves, 1909	24.81	....

IV. NICOTINE IN TOBACCO COMPOUNDS.

The insecticidal value of a tobacco compound depends upon the amount of nicotine it contains. The following determinations were made for the Entomological Division. Numbers 1315, 1312, 1311 are commercial preparations. Numbers 1313 and 1314 are the natural product.

Analyses of tobacco compounds for nicotine.

Lab. No.	Name.	Nicotine direct distillation, percent.	Nicotine ether extraction, percent.
1315	To-Bak-Ine	38.80	39.06
1312	To-Bak-Ine	40.94	43.37
1311	Tobacco extract "Rose Leaf"	....	1.73
1313	Tobacco leaves	2.91	....
1314	Tobacco stems	0.40	....

V. LIME, LIMESTONE AND MARL.

Analyses of Burned Lime.

Lab. No.	Manufacturer.	Calcium oxide, percent.	Magnesium oxide, percent.
2287	Northern Lime Co., No. 1	83.00	15.14
2290	Northern Lime Co., No. 2	79.64	19.02
2291	Northern Lime Co., No. 3	83.40	13.00
2303	Alpena Lime Works & Stone Quarry	81.90	1.08
2304	Ohlemacher Lime Co., Sandusky, Ohio	68.37	19.40
2653	Northern Lime Co	86.95	5.78
2643	Ash Grove Lime & Portland Cement Co	92.71	1.34

Analyses of Limestone.

Lab. No.	Manufacturer.	Calcium carbonate, percent.	Magnesium carbonate, percent.	Iron and aluminum oxides, percent.	Silica, percent.	Organic matter, percent.	Moisture, percent.
2309	Bellevue Limestone, No. 1	97.41	0.71	0.62	0.96	0.15	0.13
2308	Bellevue Limestone, No. 2	83.19	0.64	0.76	14.96	0.22	0.10
2307	Bellevue Limestone, No. 3	85.98	0.61	0.45	12.65	0.29	....
2292	Church Quarry Co	80.41	8.51	....	....	....	....
2577	Church Quarry Co	89.88	5.10	....	4.80	....	....
2645	Church Quarry Co	87.80	7.35	....	....	....	....
2305	U. S. Crushed Stone Co	53.52	46.06	....	....	....	....
2646	Buffalo Fertilizer Co	87.21	3.51	....	....	....	....

Analyses of Marl.

Lab. No.	Location.	Moisture, percent.	Calcium carbonate, percent.	Insoluble material, percent.	Organic matter, percent.
2298	Gagetown, Mich., No. 1	16.26	79.41	1.38	2.95
2298	Gagetown, Mich. No. 2.	45.72	51.83	1.85	0.60
2306	Kalamazoo, Mich	0.60	94.30	0.56	1.14
1931	Kalamazoo, Mich	....	92.50	1.15	....
1652	Allen, Mich	0.52	92.50	4.60	....
1924	Grandville, Mich	35.16	62.35	1.96	....
2247	Caro, Mich	....	90.71	1.17	....
2245	Manistee, Mich	....	90.52	....	....
2272	Greenville, Mich	....	56.03	....	....
2821	Ionia, Mich	....	92.21	....	....
2674	Orangeville, Mich	....	94.25	....	....
2672	Hartford, Mich	26.25	62.89	2.39	....

VI. ASHES.

The results in the following table demonstrate that it is unsafe to buy wood ashes for fertilizing purposes except subject to chemical analysis. The samples here reported vary from 0.35% to 10.13% potash. Seventy-nine per cent of the samples are below 4% and only 21% are above 5% potash.

Analyses of Ashes.

Lab. No.	Name.	Moisture. percent.	Potash. percent.	Phosphoric acid, percent.
1636	Wood ashes, hickory	0.30	10.13	....
2513	Wood ashes, hickory	....	7.22	....
1634	Wood ashes, cottonwood	1.85	9.05	....
1632	Wood ashes	0.15	0.63	....
1633	Wood ashes	1.07	0.35	....
1634	Wood ashes	1.82	2.49	....
1635	Wood ashes	4.40	3.65	....
1631	Wood ashes	0.85	3.03	....
1638	Wood ashes	1.50	2.68	....
1637	Wood ashes	0.22	5.37	....
1639	Wood ashes	0.32	1.54	....
2507	Wood ashes	....	0.50	1.10
1923	Wood ashes	16.17	1.86	....
1850	Wood ashes	....	3.52	1.22
2511	Wood ashes	....	1.13	....
2512	Wood ashes	....	1.16	....
2514	Wood ashes	....	1.39	....
2515	Wood ashes	....	0.79	....
2516	Wood ashes	....	1.03	....
2517	Wood ashes	....	1.23	....
2518	Wood ashes	....	5.18	Calcium carbonate.
2664	Wood ashes	....	3.00	62.32
2665	Wood ashes	....	0.84	64.36
2673	Wood ashes	....	0.38	80.13
1628	Corn cob ashes	....	32.40	....

VII. MATERIALS USED FOR FERTILIZING PURPOSES.

(1) *Paunch Manure.*

Samples 2253, 2254 and 2255 were taken from a pile that had been exposed to the weather four or five years. Number 2253 was taken one foot from the surface, No. 2254 was taken two feet from the surface, and No. 2255 was taken three feet from the surface. Number 2256 was fresh paunch manure. For the sake of comparison the analysis of a sample of barnyard manure is also given.

Analyses of Paunch Manure.

Lab. No.	Name.	Moisture, percent.	Nitrogen, percent.	Phosphoric acid, percent.	Potash, percent.
2253	Paunch manure, No. 1	76.92	0.22	0.06	0.05
2254	Paunch manure, No. 2	80.41	0.24	0.12	0.01
2255	Paunch manure, No. 3	80.00	0.28	0.20	0.07
2256	Paunch manure, No. 4	69.69	0.24	0.21	0.02
....	Barnyard manure	68.87	0.49	0.32	0.43

(2) *Fertilizer Constituents in Tobacco.*

The fertilizing constituents of tobacco, more especially potash, varies within wide limits and consequently it should always be purchased on a guaranteed basis or subject to chemical analysis.

Analyses of Tobacco samples.

Lab. No.	Name.	Nitrogen, percent.	Phosphoric acid, percent.	Potash, percent.
2487	Tobacco refuse	1.98	....	7.36
1617	Coarse ground tobacco	1.70	0.68	6.15
1307	Tobacco dust, No. 1	1.73	0.94	9.62
1306	Tobacco dust, No. 2	0.96	0.64	0.84
1616	Tobacco dust, No. 3	1.81	0.62	6.04

(3) *Peat Filler for Fertilizers.*

The three samples reported were sent to the laboratory by Dr. Chas. A. Davis and were prepared by the Crescent City Manufacturing Co., Crescent City, Fla. Several samples of Michigan peat have been analyzed in this laboratory in connection with other work and they agree very closely in nitrogen content with the sample of raw peat, No. 2131, given in the table.

Analyses of Peat Filler.

Lab. No.	Name.	Moisture, percent.	Nitrogen, percent.
2131	Raw peat	17.19	2.53
2132	Peat filler	10.04	2.12
2133	Ammoniated peat filler	....	2.81

(4) *Miscellaneous Materials.*

Lab. No.	Name.	Nitrogen, percent.		Phosphoric acid, percent.	Potash, percent.
1849	Garbage tankage		2.16	6.31	0.79
2946	Ground beans		3.99	0.52	1.52
2466	Guano (Chihuahua, Mexico)		11.47	2.62	....
2643	Apple pomace		0.20	0.15	0.21
		As nitrate.	As sulfate.		
2509	Bonora (nature's plant food)	4.10	10.96	4.12	5.18

VIII. LIME-SULFUR SOLUTIONS.

The samples reported in the table given below were all received during 1910 and 1911. All but two of the samples are commercial preparations. From the results given in the table it appears that there is quite a considerable variation in the amount of total sulfur in solution and that different samples from the same company may vary as much as 7%. Number 2296, Horicum, is a thick paste and must be dissolved in water before using.

Analyses of Lime-Sulfur Solutions.

Lab. No.	Name.	Baumé.	Total calcium, CaO. percent.	Total sulfur, percent.	Sulfide sulfur, percent.	Thio-sulfate sulfur, percent.	Sulfate sulfur, percent.
2301	Jas. A. Blanchard Co	30°.2	9.18	23.27	20.86	2.00	0.41
2285	Jas. A. Blanchard Co		13.12	26.63			
2275	Jas. A. Blanchard Co		9.17	19.77			
2917	Jas. A. Blanchard Co	29°.4	9.13	21.87	21.08	1.27	0.07
2660	Jas. A. Blanchard Co	31°.4	9.77	23.89	23.05	1.03	0.12
2299	Grasselli Chemical Co	33°.4	10.36	26.66	24.76	1.95	
2274	Grasselli Chemical Co		9.34	19.45			
2302	Sherwin-Williams Co	32°	9.36	25.43	22.56	1.85	1.02
2300	Niagara Brand	34°	10.95	26.55	25.27	1.51	
2295	Dow Chemical Co		10.50	26.81			
2720	Dow Chemical Co	32°.2	9.63	24.69	24.49	0.91	0.08
2649	Dow Chemical Co	31°.8		24.97	24.00	0.84	
2276	Toledo Rex Spray Co		9.63	20.53			
2294	Toledo Rex Spray Co	33°	10.21	26.09			
2490	Toledo Rex Spray Co	33°	10.38	26.23			
2918	Toledo Rex Spray Co	27°.8	8.27	20.72	19.68	1.48	0.07
2648	Toledo Rex Spray Co	30°		23.30	22.41	0.92	
2661	Toledo Rex Spray Co	29°.5	9.46	23.40	22.17	1.30	0.14
2488	Home Made No. 1	34°.4	6.32	14.61	Sediment. 16.59		
2489	Home Made No. 2	34°.2	7.93	17.70	12.90		
2296	Horicum		10.67	20.40	16.19		Chlorine. 5.13

IX. INSECTICIDE MATERIALS.

Analyses of Arsenate of Lead.

Lab. No.	Manufacturer.	Moisture, percent.	Total arsenic, As_2O_3, percent.	Lead oxide, percent.	Soluble arsenic, As_2O_3, percent.
2491	Toledo Rex Spray Co.	54.27	15.56	....	....
1329	Vreeland Chemical Co.	36.56	18.77	39.69	....
2493	Hemingway's London Purple Co., Ltd.	46.50	17.79	....	0.28
2992	A. B. Ansbacher Co.	26.00	19.00	....	0.56
2582	Jas. A. Blanchard Co.	23.93	15.76	....	0.66

Analyses of Paris Green.

Lab. No.	Manufacturer.	Total arsenic, As_2O_3, percent.	Total copper, Cu., percent.	Soluble arsenic, As_2O_3, percent.
2571	DeVoe & Raynolds	57.44	....	3.21
2230	Gleaner Clearing House Association	57.84	29.29	1.47
2858	Jas. A. Blanchard Co.	54.08	....	6.88
2838	Jas. A. Blanchard Co.	54.50		....
2610	Jas. A. Blanchard Co.	56.20	30.36	1.90

THE USEFULNESS OF CURVES IN THE INTERPRETATION OF MICROBIAL AND BIOCHEMICAL PROCESSES

BY OTTO RAHN

Technical Bulletin No. 5.

FOREWORD.

The general discussion contained herein is so intimately pertinent to the many problems in the broad fields of dairy and soil microbiology that it seems wise to issue it in the form of a separate bulletin. To make it a part of any bulletin representing specific investigations would be abortive and much of its utility would be lost.

Such general surveys of knowledge serve a function almost as great as delving into unknown recesses for new facts, because they not only have a tendency to formulate findings already available, but they effectively shape the course of investigations and institute systematic effort. Accordingly, the author has served a purpose which will be helpful in the investigations of this institution and other institutions as well.

CHARLES E. MARSHALL.

INTRODUCTION.

There will probably be considerable doubt expressed as to the value or even the possibility of interpreting microbial or biological processes mathematically.

As to the value, I desire to call attention to the wonderful evolution in the understanding of chemistry by the introduction of physical, or mathematical chemistry. The exact determination of all factors involved gave an entirely new interpretation to chemical reactions.

As to the possibility, there may be some question in determining life processes, such as those of bacterial activity, as accurately as a chemical reaction. It is still an open question whether or not life manifestations are a mere physico-chemical process. Our deficient knowledge of chemistry and the inability of controlling all factors involved have not as yet permitted a definite answer. We assume, however, that under the same physical and chemical conditions the same changes will take place; otherwise, physiological experiments will be useless. The possibility of applying mathematics to bacteriological processes cannot be disregarded therefore, if all the conditions involved in them are under control. Difficulties will arise mainly from the inaccurate methods of analyzing the products or counting the bacteria, but the difficulties of a method cannot prevent the use of it to advantage.

The natural development of all science leads towards an absolutely exact formulation of facts. The physiology of fermentation is one branch of this science. If it is sufficiently advanced to permit the application of mathematics, it will be fitting to make it; if not, the weak points should be pointed out, and the gaps of our knowledge filled.

DISCUSSION.

The changes taking place in solutions of organic compounds may be of various natures. The three most common possibilities are:

1. Purely chemical changes, following the law of Guldberg and Waage.
2. Purely enzymic processes.
3. Microbial or biological processes.

The difference existing in the three processes consists mainly in the behavior of the "active mass." In the purely chemical changes, the active mass is represented by the concentration of the acting substances and decreases as the process goes on. In the saponification of fat by alkali, both fat and alkali decrease by reacting upon each other, and

the reaction proceeds more slowly as the reaction advances. In the enzymic process, one part of the active mass, that is, the enzyme, remains constant. It is a peculiarity of enzymes to cause decompositions without being weakened in their activity. This would cause a constant rate of decomposition, were it not for the fact that the decreasing concentration of the substance acted upon and the increase of the decomposition products check it. For this reason, the actual rate decreases. In bacterial changes, we have an increasing "active mass." The number of acting cells increases for a long time, and consequently, the velocity of the decomposing process increases also. These various possibilities of changes occurring in organic compounds give two types of curves, easily to be distinguished from each other.

The curves of the purely chemical processes can be plotted from their mathematical equations. A reaction, where only *one* kind of molecules changes its concentration considerably, is called a *unimolecular* reaction (e. g., the inversion of saccharose by acids). A *bimolecular* reaction, where the concentration of *two* kinds of molecules is changed, is represented by the saponification of esters by alkali. The equations are not essential for the following discussion, since we are interested only in the shape of the curves; they are, according to Nernst (theoretische Chemie, 1900, p. 513):

For *unimolecular* reactions $K = \frac{1}{t} \frac{\ln a}{a-x}$

For *bimolecular* reactions $K = \frac{1}{t} \frac{x}{(a-x)a}$.

For *trimolecular* reactions $K = \frac{1}{t} \frac{x\ (2a-x)}{2a^2\ (a-x)^2}$.

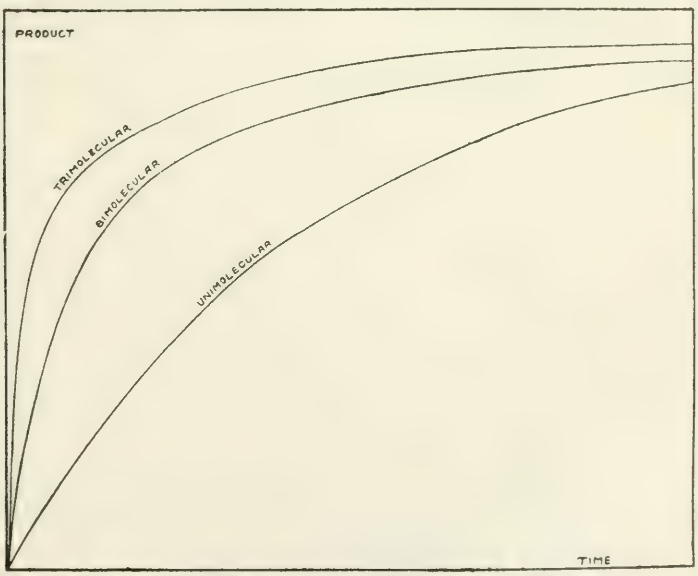


Fig. 1. *The Law of Guldberg and Waage.*

This mathematical formulation of the analytical data enabled van 't Hoff to state definitely the mechanism of chemical reactions which heretofore had been interpreted in various ways.

Figure 1 shows the curves plotted from the mathematical equations of the *unimolecular, bimolecular,* and *trimolecular* reactions.

The mathematical formulation of the enzymic curves is not as yet definitely settled, but we can obtain the curves easily from the data of analyses. Figure 2 is a typical enzymic curve, illustrating saccharose inversion by invertase. The data are taken from Duclaux, Traité de microbiologie, t. II p. 154).

ACTION OF INVERTASE.

After	5 minutes	3.1%	sugar	inverted.
"	15 "	9.8%	"	"
"	30 "	19.2%	"	"
"	57 "	33.6%	"	"
"	90 "	45.8%	"	"
"	120 "	58.5%	"	"
"	150 "	67.4%	"	"
"	210 "	79.9%	"	"
"	240 "	84.4%	"	"
"	270 "	87.3%	"	"
"	320 "	95.1%	"	"
"	1470 "	99.2%	"	"
"	48 hours	100.0%	"	"

Figure 3 is another enzymic curve, illustrating the decomposition of the protein of raw milk by the galactase, the natural proteolytic enzyme of milk. The milk was treated with an antiseptic to inhibit the growth of micro-organisms. The difference between this enzyme and the invertase consists mainly in the velocity of action, the one accomplishing a

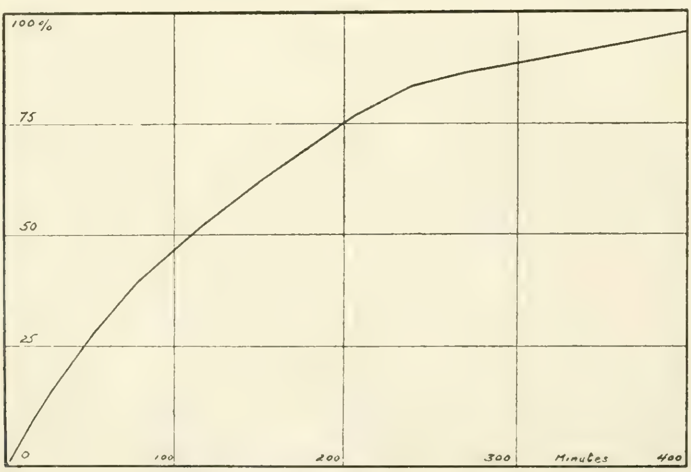


Fig. 2. *The Action of Invertase.*

greater change in a few minutes than the other caused in many weeks. Nevertheless, the form of the two enzymic curves is much alike, if drawn to comparable scales. The data for this curve are taken from the experiments of VanSlyke, Harding and Hart (cited in Lafar, Handbuch, Band II, p. 149).

ACTION OF GALACTASE IN MILK.

Age of Milk.	Soluble Nitrogen.
Fresh	9.33% of total nitrogen.
7 days	11.77% " " "
21 "	15.91% " " "
49 "	21.59% " " "
112 "	32.82% " " "
192 "	37.63% " " "

These three curves demonstrate that there is very little difference in the purely chemical and enzymic processes, as far as the form of curves is concerned, though their mathematical equations are quite different. It is impossible to decide by the picture of the curve alone whether we are dealing with an enzyme or with the law of Guldberg and Waage.

Quite different from these curves are the changes produced by growing and multiplying organisms. The difference is mainly, and in most cases only, the increase of the active mass in these processes. The simplest illustration is the following:

An acid-producing bacterium is inoculated into a sugar solution. In the time required by these bacteria to double their number, a certain

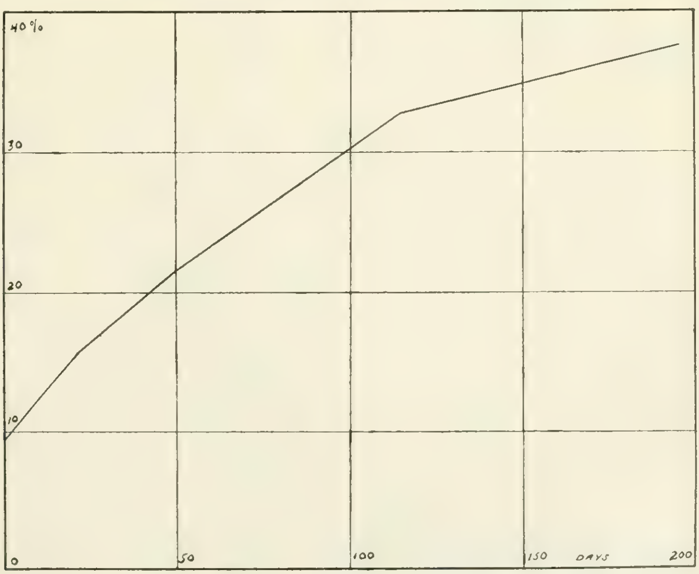


Fig. 3. *The Action of Galactase in Milk.*

amount of acid a will be produced. The second generation consists of twice as many cells which will, in the same time, produce twice as much acid as the original number, and this is added to the first acid, making the total quantity $3a$. The third generation consisting of four times as many cells as the original, will produce four times as much acid, making the total $4a + 3a = 7a$. The fourth generation produces eight times as much acid, etc. The resulting curve is shown in Figure 4. There is evidently, in the beginning, a tendency in the curve to become gradually parallel to the ordinate. This is, however, naturally limited by the restriction in the multiplication of the bacteria. After a certain time, the growth of the acid producers will become slower and slower and finally will cease. As soon as this takes place, the active mass is constant, and when the active mass is constant, we have an enzymic curve. The enzymic curves have the tendency to run gradually parallel to the base line, and this combination of the two curves, the "curve of growth" with the enzymic curve, gives rise to the typical "fermentation curve." If the number of bacteria decreased soon after reaching the maximum, the resulting curve from this moment would correspond to the law of Guldberg and Waage, giving practically the same path of curve.

It is not necessary, however, for a typical fermentation curve that the multiplication of micro-organisms follow the geometrical progression as in the example mentioned above. Any increase of active mass will cause an increase in the rate of fermentation, or an increasing angle of elevation, and we obtain fermentation curves with yeasts and moulds as well as with bacteria, though their laws of multiplication are different. Even growing animals and growing green plants must give similar curves for their products. It is, of course, understood that the factors influencing growth and fermentation, as e. g., temperature,

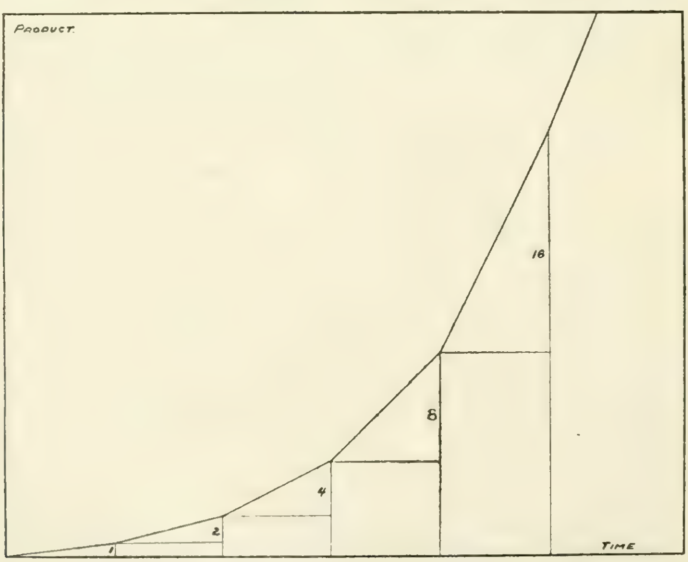


Fig. 4. *The Theoretical Fermentation Curve.*

oxygen supply, light, etc., must remain constant in order to give comparable data.

In speaking of "fermentation curves" from the one view point and "enzymic curves" from the other, it is not intended at all to oppose the general conception that probably all fermentations are caused by enzymes. The word "fermentation" is used in its widest meaning as a decomposition caused by micro-organisms, while the term "enzyme" is applied to the chemical compound enzyme which, independent of the cell, acts but does not multiply. It is really a distinction between the organized and unorganized ferments of forty years ago, when it was not known that the unorganized ferment is a product of the organized.

The difference can be demonstrated quite plainly by the following example: A drop of a pure culture of a liquefying bacterium is spread over the surface of sterile gelatin in a test tube. The amount of liquefaction is measured daily and recorded in millimeters. A three-days'-old gelatin culture of the same organism is shaken with xylol for an hour to kill all bacteria, and 1 cc. of the liquefied part is transferred into a test tube with gelatin of the same diameter as the above culture; the liquefaction is measured daily. In the first tube, we have a fermentation, i. e., decomposition of gelatin by an organism, in the second, we have enzymic action, all bacteria being killed. In an experiment with *Bacillus subtilis,* the following data were obtained:

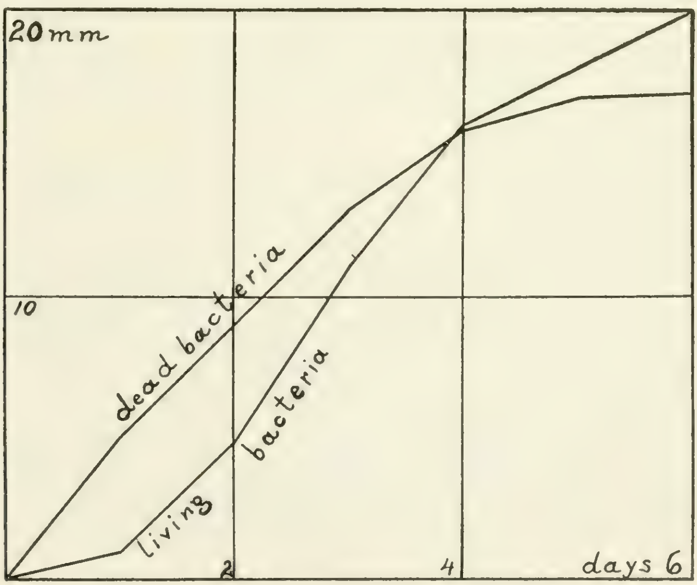


Fig. 5. *Gelatin Liquefaction by Living and Dead Bacteria.*

AMOUNT OF GELATIN LIQUEFIED.

	Living culture.	Dead culture.
After 1 day	1 mm.	5 mm.
" 2 days	5 mm.	———
" 3 days	11 mm.	13 mm.
" 4 days	16 mm.	16 mm.
" 5 days	19 mm.	17 mm.
" 6 days	20 mm.	17 mm.

The difference between the two curves is plain, though the method of analysis is very inaccurate. The curve of the dead bacteria has from the first moment a decreasing angle of elevation, while the curve of the living bacteria becomes at first steeper, and only after the third day does it resemble that of the dead bacteria of the first day.

In the first three days, the angle of elevation or the rate of liquefaction increases. This increase is due to an increase of the active mass, namely, the bacteria or the enzymes secreted by these bacteria. During the fourth day, the rate of liquefaction has decreased a little, the angle of elevation being a little smaller. We must conclude that the active mass has ceased to multiply and is possibly decreasing. The curve of liquefaction, running at first more and more parallel to the ordinate, after three days turns the other way, and has the tendency to become parallel to the base line. The mathematician calls the point where a line curving in one direction changes to another direction, the point of inflection. This point is the characteristic point of the fermentation curve. The part beyond the point of inflection is in no way essentially different from the enzymic curve, but the part before, indicating the "increase of active mass" is typical for changes brought about by growing organisms.

The point of inflection indicates the moment when the maximum number of bacteria is present. Consequently, we can recognize a curve as a fermentation curve only when the analysis of the products is begun before the maximum number is reached. At the point of inflection begins the enzymic curve, characterized by no increase of active mass.

If, instead of using the total products, we would plot the curve from the daily or hourly increase, we get a maximum corresponding to the point of inflection. This is a mathematical law; the curve of the increase is the differential curve or derivative of the process itself, and the point of inflection in any curve is necessarily followed by a maximum (or minimum) in the differential curve.

As one of the simplest examples, we shall discuss first lactic fermentation in pure culture. The following data are taken from a paper by Schierbeck (Archiv fuer Hygiene, Bd. 38, p. 299).

ACID PRODUCTION IN MILK.

Hours after Inoculation.	Degrees of Acidity	
	at 28° C.	at 35° C.
0	15	15
5	16	17
7	17	20
10	22	41
11	28	56
13	44	66
15	64	75
25	88	84
32	96	87
48	101	88

At both temperatures, we notice plainly the increase of the active mass in the beginning of the fermentation, resulting in an increasing angle of elevation. This continues till the acidity of about 50° is reached, then the curve begins to turn the other way. The point of inflection indicates the moment when the bacteria cease to increase. In our curve, we can readily see that in the milk at 35°C., the maximum number of lactic bacteria must have been reached about 9 hours after inoculation; in the other sample, about 14 hours.

Another example of a combination of two fermentations is illustrated in the black line of Figure 7, representing the acid production and destruction in market milk exposed to the air in a dish with large sur face. The titrations on 20 successive days gave the following degrees of acidity:

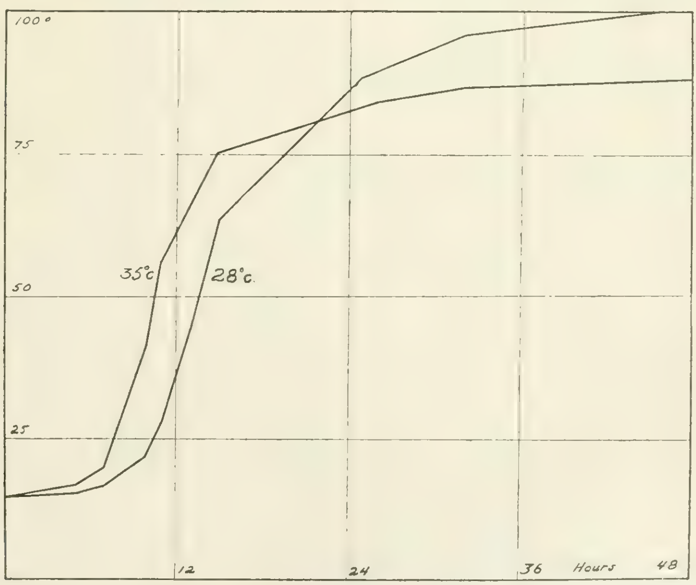


Fig. 6. *The Lactic Fermentation.*

MILK KEPT IN AN OPEN VAT.

Days.	Acidity.	Acid destroyed.	Daily increase.
	(black curve)	(dotted curve)	
0	12	..	—
1	24	..	+12
2	52	..	+28
3	104	..	+52 maximum.
4	128	..	+24
5	136	..	+ 8
6	136		
7	132	0	0
8	134	4	− 4
9	130	2	0
10	98	6	− 4
11	78	38	−32 minimum.
12	64	58	−20
13	52	72	−14
14	40	84	−12
15	34	96	−12
16	30	102	− 6
17	28	106	− 4
18	26	108	− 2
19	26	110	− 2
		110	0

The first process reaches its maximum after five days at 136° acid. The curve shows a plain fermentation curve with the point of inflection at the third day corresponding to a maximum in the curve of increase (See table). Then follows the decrease of acid, caused probably by *Oidium lactis.* This again is a typical fermentation curve. To show this more plainly, the curve of acid destruction was plotted, (third column of the table), beginning with the maximum acidity at the fifth day. The dotted curve in Figure 7 giving the amount of acid destroyed at different days, is of course nothing but the inverse of the original curve. In this

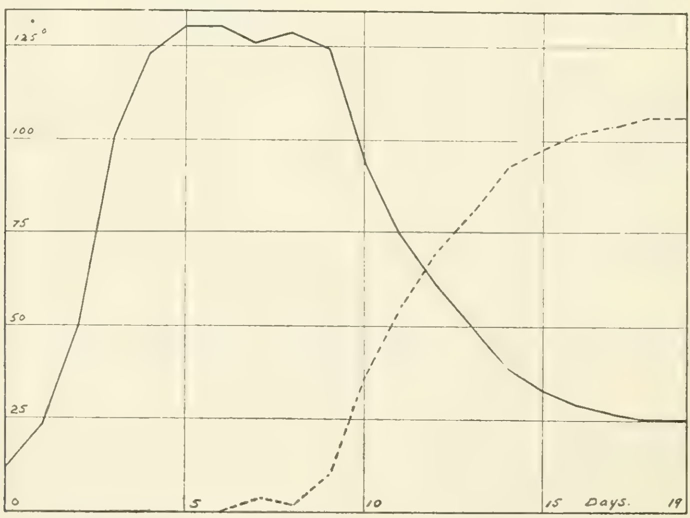


Fig. 7. *Increase and Decrease of Acid in Unheated Milk.*

case, instead of plotting the curve from the amount of the products of fermentation, we used the amount of food disappearing. The point of inflection corresponds to the minimum of the increase, which is the maximum of the acid destruction.

The next two illustrations give two types of cheese ripening. It was the difference of the following two figures that called my attention first to the meaning of the form of these curves. They show the soluble nitrogen (in per cents of total nitrogen) at different stages of the ripening process of soft and hard cheese. Both curves are plotted from data coming from the Geneva Experiment Station, obtained at about the same time, and are, therefore, directly comparable.

Figure 8 represents the ripening process of the camembert cheese. The curve is quite irregular, probably due to the fact that different cheeses had been used for the analysis at different ages. But there is no doubt about its being a plain fermentation curve similar to the dotted line.

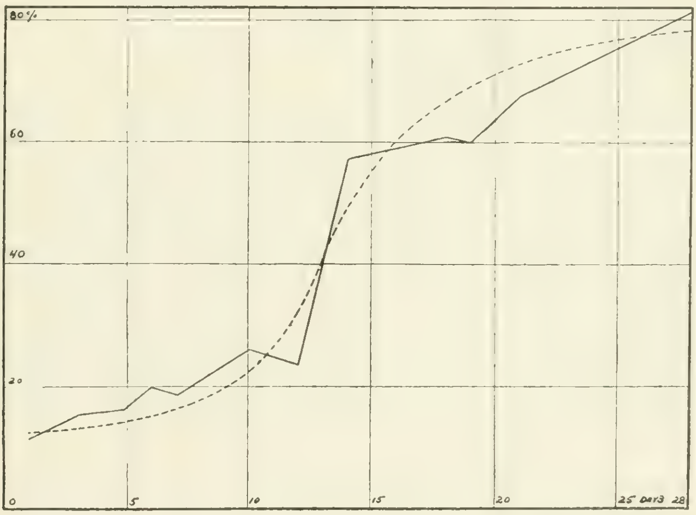


Fig. 8. *Water-Soluble Nitrogen in Camembert Cheese.*

RIPENING OF CAMEMBERT CHEESE.

(Geneva Exp. Sta. Technical Bul. No. 5 (1907.))

Age.	Water soluble nitrogen.
1 day	11.72% of total nitrogen.
3 days	15.02% " " "
5 "	16.02% " " "
6 "	19.78% " " "
7 "	18.51% " " "
10 "	25.98% " " "
11 "	25.68% " " "
12 "	23.79% " " "
14 "	56.51% " " "
18 "	60.69% " " "
19 "	60.00% " " "
20 "	63.79% " " "
21 "	67.55% " " "
28 "	80.88% " " "

The main factor in this ripening is not a bacterium, but a Penicillium, the spores of which are scattered upon the surface of the cheese when it is one or two days old. "These germinate and grow, producing a white, velvety mass on the cheese which turns a dirty green about the tenth or twelfth day, due to the ripening of the spores." With the ripening of the spores the mold has reached nearly the limit of its growth; the point of inflection of our curve at the 13th day agrees very nicely with this fact.

The ripening of the cheddar cheese is, according to Figure 9, an entirely different process. There is no distinct increase of the angle of elevation, it seems rather like an enzymic curve; we may also compare it with the camembert curve from its thirteenth day, or still more accurately with the slow action of the galactase in milk. (Figure 3).

RIPENING OF CHEDDAR CHEESE.

(Geneva Exp. Sta. Technical Bul. No. 4 (1907)).

Age.	Water soluble nitrogen in per cent of total nitrogen.		
Fresh	4.68%	3.27%	3.77%
2 days	7.73%	4.19%	4.75%
4 days	9.11%	7.25%	5.87%
7 days	11.02%	9.42%	8.26%
14 days	18.60%	16.01%	10.16%
1 month	.....	19.58%	16.84%
2 months	28.68%	29.21%	23.21%
3 months	.....	.....	25.34%
4 months	34.39%	31.16%	24.31%
5 months	31.53%	.....	.....
6 months	43.22%	34.34%	.....

The nature of the ripening process of cheddar cheese has not been discovered yet. It may be bacterial or enzymic action, or both. (The

purely chemical ripening has never been taken into serious consideration).

The ripening curves of our three cheeses have no point of inflection. There may have been a point before the first analysis of the cheeses was made, i. e., while the cheeses were in the press or very soon after this. At this time, the searching for the specific bacteria would be most likely successful, since they would be found in largest number. Harding and Prucha (Technical Bul. No. 8 of the Geneva Exp. Sta. 1908, p. 180) found the lactic bacteria in cheddar cheese to reach their maximum number about four days after the cheese leaves the press.

Against the theory of bacterial ripening stands, however, the very low point of inflection, if we suppose such a point at the first day after the cheeses leave the press. In all previous fermentation curves, this point is very near to one-half of the final amount of fermentation products, while in this case the final amount of water soluble nitrogen is about 30% of the total nitrogen and the point of inflection would occur at about 4%. There is a certain amount of water soluble nitrogen already present in milk, about 0.06 g. in 100 cc. of milk or in 87 g. of water. Figuring on an average of about 30% of water in cheese, this soluble nitrogen from fresh milk would amount to only 0.02% of the total cheese substance, while the soluble nitrogen of the cheese when leaving the press is about 0.12% to 0.20%. There must have been a rapid protein decomposition in the very short time elapsed from the moment of adding the rennet to the milk until the time when the pressing is finished. This rapid ripening in the first days speaks decidedly against an important rôle of bacteria, if we consider the solubility of the nitrogen as the characteristic of ripening. This is not entirely true, however, since the commercial value of hard cheese depends more upon the

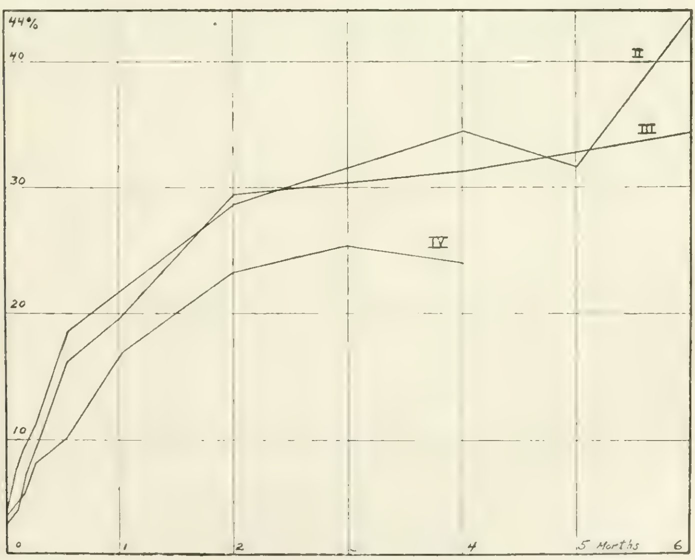


Fig. 9. *Water-Soluble Nitrogen in Cheddar Cheese.*

flavor than upon the solubility of nitrogenous compounds. This part of the ripening process cannot be included in our discussions, unless we find an accurate method of determining flavors quantitatively.

It may be said against this discussion of cheese ripening that the factors important for microbial life are not constant, changing from the nearly neutral milk to a salted, pressed, acid curd. This change will naturally affect the development of micro-organisms, but from the time our curves begin to tell the story of ripening the conditions are nearly constant, excepting the acidity. After the first two days, when 100 cc. of the extract require about 140 cc. of n-10 alkali to be neutralized, the acidity increases very slowly, amounting to about 190 cc. after two weeks and about 220 cc. after four months; later it decreases slowly. This change in acidity will naturally influence the curve to some extent, but not enough to convert a fermentation curve into an enzymic curve.

Whether the ripening process of the Swiss cheese follows the curves of the cheddar cheese or not, I am not able to say, since I have not succeeded in getting sufficient data for an exact curve. Weigmann (in Lafar, Handbuch II, p. 158) quotes from von Freudenreich that the autolysis of fresh Swiss cheese is very insignificant while it is quite vigorous in old cheese. That speaks plainly for a microbial curve.

A curve similar to the cheddar cheese ripening is found in the increase of amid nitrogen in cold storage butter (Rahn, Brown and Smith, Technical Bul. No. 2 of Michigan Exp. Sta. (1909), p. 29). The butter kept

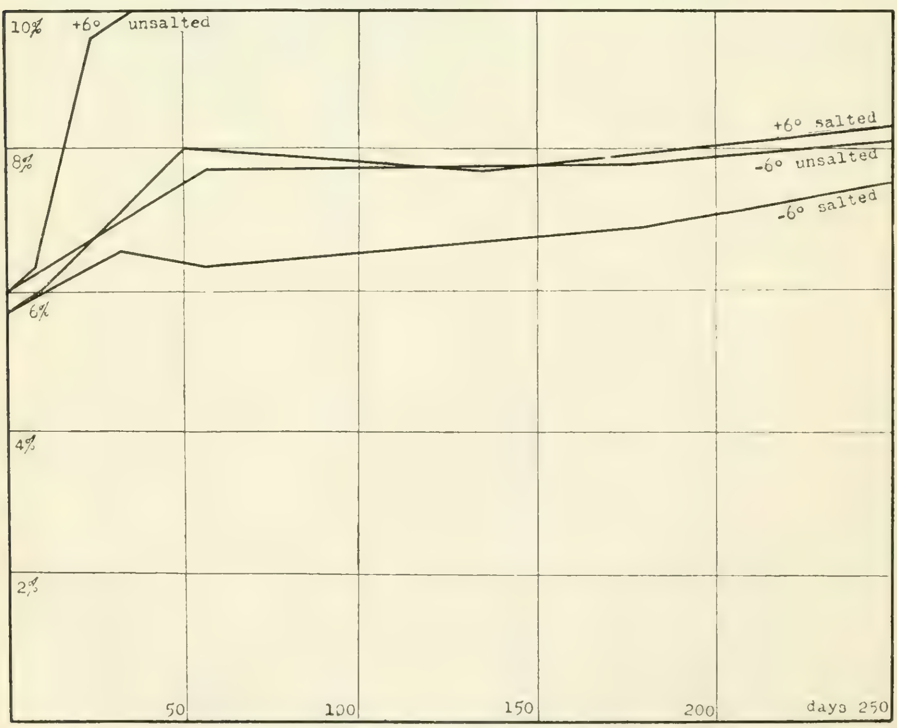


Fig. 10. *Amid Nitrogen in Butter.*

at +6°C. without salt has a distinct point of inflection, the decomposition of protein is caused by molds developing in that butter, while the other samples show a distinct curve of enzymic or chemical change. We must conclude from this that if the protein degradation in cold storage butter is due to micro-organisms, these had reached their highest number at the time the investigation began, and did not multiply after the butter was put in storage. The conditions of the butter remain practically the same after it has once reached the temperature of cold storage, since the moisture in butter, especially in salted butter, does not freeze.

Another example is the nitrification in soils after addition of ammonium salt. Coleman (Centralblatt fuer Bakteriologie II, Bd. 20, p. 408) found that the addition of dextrose increases the rapidity of nitrification.

NITRIFICATION IN SOIL.

Additions to soil.	Nitrate-nitrogen per kg. of soil.				
	fresh.	8 days.	14 days.	20 days.	27 days
I. Ammonium salt only.............	20 mg.	34.5 mg.	83.5 mg.	271.9	6C6.0
II. Ammonium salt + 0.2 % dextrose...	20 mg.	22.3 mg.	123.2 mg.	426.3	668.7
III. Ammonium salt + 0.5 % dextrose...	20 mg.	45.9 mg.	183.9 mg.	452.8	654.5

Plotting the curves from the above table, we find a typical fermentation curve, proving a large increase of nitrifying bacteria. With our present methods of counting nitrifying bacteria, it would have needed an ex-

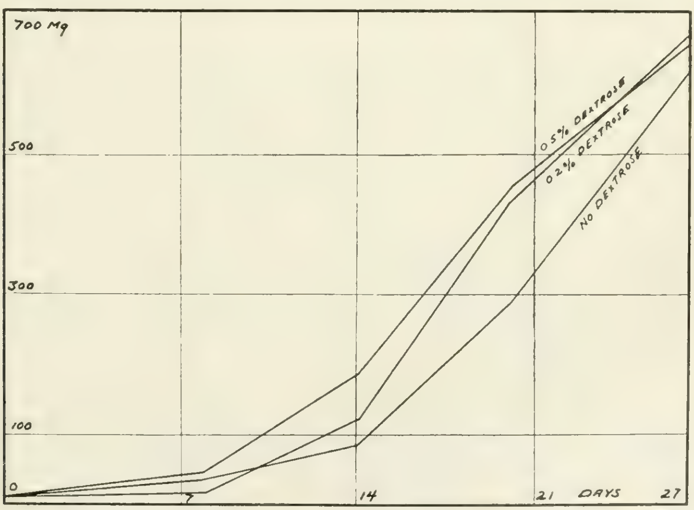


Fig. 11. *Nitrification in Soil with and without Dextrose.*

ceedingly tedious and uncertain experiment to prove an increase, while the curve shows plainly that the nitrifying bacteria in the soil treated with dextrose reached their maximum number at about the twentieth day, while without dextrose this point was not reached until about the twenty-seventh day.

It seems quite probable from this discussion that dextrose has a stimulating influence, not upon the nitrification process itself, but upon the quantity of nitrifiers. It is probably used as food by these nitrifiers, either directly or after having been broken up into simpler compounds (e. g., CO_2) by other soil bacteria.

The next curve is an illustration for the necessity of determining as many points as possible of a process to be analyzed by the form of its curve. The data of Figure 12, representing the nitrification in soil with ammonium salt, are taken from the paper of Coleman, mentioned above.

NITRATE NITROGEN IN SOIL WITH AMMONIUM SALT.

In the beginning....................	71.45 mg. per kg. of dry soil.
After 3 weeks	316.82 mg. per kg. of dry soil.
After 5 weeks	503.88 mg. per kg. of dry soil.
After 7 weeks	501.91 mg. per kg. of dry soil.
After 9 weeks	514.97 mg. per kg. of dry soil.

The curve in straight black lines gives the actual result, and the two dotted lines are two interpretations, both possible, according to the given facts. If we did not know that the nitrification is really a process caused by micro-organisms, and that the fermentation curve is the only interpretation possible, the given data would not show this. It is also evident that the determination of more points towards the end of the fermentation does not improve our knowledge of the curve much. The points of greatest importance are those which demonstrate the point of inflection, and this necessitates several analyses at the beginning of the fermentation. Comparatively little attention is paid generally to

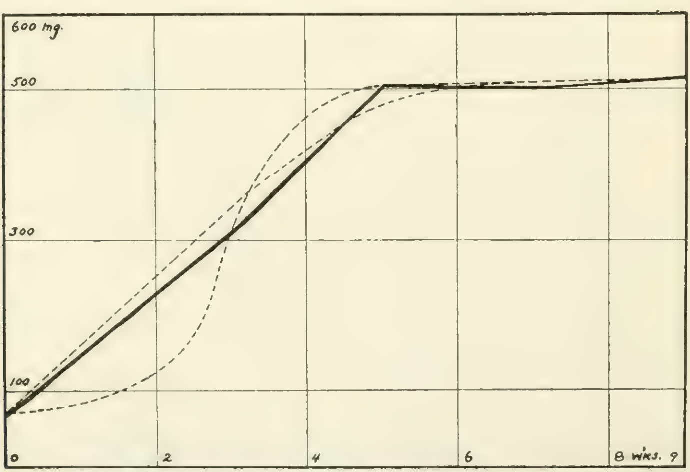


Fig. 12. *Nitrification in Soil, and Two Possible Interpretations.*

the first stage of development, only the final products have been considered as important. This is natural from the commercial standpoint of the brewer, distiller, and butter-maker, but the scientist who aims at a complete understanding of the physiological process has to consider all phases of the growing cultures.

An illustration for this fact can be given in the results obtained by the Remy method for testing soils. It consists in inoculating a sterile peptone solution with a certain amount of soil and determining the amount of ammonia produced after a certain number of days. Besides ammonia production, other soil properties, like nitrification, nitrogen fixation, etc., are tested in corresponding solutions. The ammonia is usually determined just once, after 3 to 8 days, under the supposition that after this time it does not increase. This is not always true, as can be seen easily from the data obtained with three Michigan soils, a muck, a sandy loam, and a very poor sand. The ammonia produced by 10 grams of soil in 100 cc. of a 1% peptone solution at 20°C. gave the following data:

AMMONIA PRODUCTION IN 100 CC. OF PEPTONE SOLUTION BY 10 GRAMS OF SOIL.

(mg. nitrogen in form of ammonia per 100 cc.).

Days.	2	4	5	6	8	10	13	15	23
Muck	10.1	48.5	64.8	79.0	95.7	104.0	110.7	113.0	110.6
	9.9	50.7	66.0	81.3	98.8	105.1	112.1	115.2	113.1
Loam	4.5	49.5	69.0	87.3	97.3	106.5	110.9	112.1	114.5
	6.3	48.7	69.3	90.9	97.9	107.5	111.8	113.0	....
Sand	1.1	6.0	13.4	27.6	52.4	72.0	99.4	99.8	102.8
	1.3	6.3	17.8	33.0	55.0	87.6	105.1	108.8	107.7

The table shows very plainly that one single determination of ammonia cannot possibly give a correct idea of the changes brought forth by the soils. After two days, the muck soil has produced about nine times as much ammonia as the sand, and the loam about five times as much. This proportion, 1:5:9 is entirely changed after four days; it is 1:8:8, muck and loam being alike. After six days, the loam is ahead, but the sand also begins to ammonify more rapidly; the relative amounts of ammonia are now 1:3:2.6. From the eighth day, muck and loam are very much alike, while the sand is coming up more and more, though not entirely reaching the other two soils; the final proportion is 1:1.1:1.1. These proportions show better than long discussions that the Remy method in its present form cannot give an understanding of the bacteriological properties of a soil. What time would be the most adequate for the distillation? At first, the muck is high, then the loam is high, and at the end, all three soils are very much alike. Even if all bacteriologists would agree to keep all cultures at the same temperature for the same length of time, the simple analysis of one culture after seven days would not give a definite knowledge of the previous and the following changes. The peculiar difference between loam and muck soil could

never be found by the Remy method, though it must certainly be based upon the character of the soils or of their bacteria. Another experiment carried on three months before the one described above, gave the same relations, though the rapidity of fermentation was higher in these midsummer soils. (Fig. 13).

AMMONIA PRODUCTION IN PEPTONE SOLUTION BY SOILS.

After	2 days.	3 days.	4 days.	6 days.
Muck	23.5 25.4	38.1 39.0	47.6 48.6	71.0 74.4
Loam	13.7 15.1	39.5 40.8	67.5 68.4	89.8 93.0
Sand	3.1 3.2	11.0 9.9	18.2 18.8	39.0 44.7

After two days the muck culture has nearly twice as much ammonia as the loam culture, after three days they are alike, after six days the loam is about 20% higher than the muck.

Whether this remarkable behavior in the ammonification by loam and muck is due to a difference in the specific flora or to chemical or physical qualities of the soil, I cannot say, but such differences of the soil should not be neglected if we are testing the bacterial qualities of our soils in the manner described.

A very remarkable feature of these last curves is the long, straight line instead of the nicely curving forms of the previous fermentation curves. We find these curves often occurring in soil fermentations. The most striking example is perhaps a series of analyses showing the acid

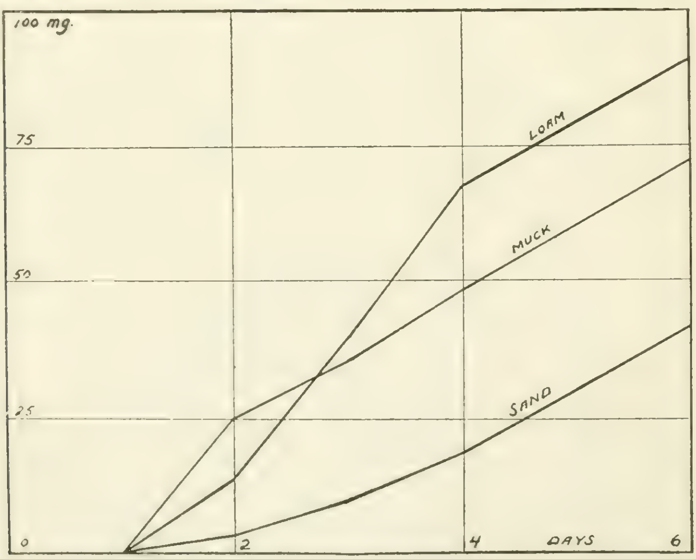


Fig. 13. *Ammonia Production by Three Soils in Peptone Solution.*

production in dextrose solution inoculated with soil (Rahn, Centralblatt f. Bakteriologie II, Bd. 20, p. 39).

ACID PRODUCTION IN DEXTROSE SOLUTION WITH SOIL.

	Days.											
	5	6	8	10	12	14	16	23	31	37	48	60
Plot No. 1....	7	9	15	21	27	35	41	44	47	48	46	43
Plot No. 2....	8	11	17	25	30	38	42	44	46	48	47	43
Plot No. 3....	4	7	13	20	26	34	39	45	44	42	38	35
Plot No. 4....	7	9	17	23	28	37	40	52	55	55	53	50
Plot No. 5....	7	11	16	23	30	36	43	53	52	54	50	47
Plot No. 6....	9	12	22	30	35	42	49	55	57	59	59	57
Plot No. 7....	8	11	18	24	31	37	44	54	56	57	57	54
Plot No. 8....	4	4	9	14	18	24	30	24	22	22	22	20

The eight plots are from the same soil treated in different ways: the kind of treatment is immaterial for this demonstration and may be looked up in the original. Since the soil contained lime, the titration was not begun until the fifth day and from the fifth to the sixteenth day, the rate of acid production is so remarkably constant that one would hardly take the lines of Figure 14 for fermentation curves. The increasing rapidity of the acid production is only shown in the first five days. Instead of the point of inflection, we have a straight line.

This seems to be the case in all solutions with a small amount of food. Fig. 15, e. g., shows the ammonia production of bacteria in a solution of peptone in distilled water.

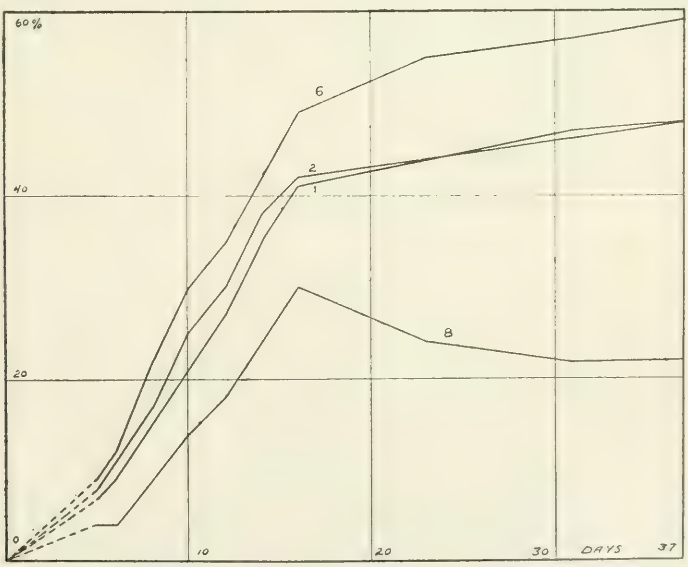


Fig. 14. *Acid Production in Dextrose Solution by Soil.*

AMMONIA PRODUCTION IN PEPTONE SOLUTION.

	2 days.	3 days.	4 days.	5 days.	6 days.	7 days.
Pure Culture	—	7.0	8.1	10.6	12.6	—
Mixed Culture	17.0	25.1	—	37.4	—	51.8

The mixed culture is taken from a similar peptone solution decomposed by soil bacteria; the pure culture was obtained by plating from this mixture. It was tried several times without success to get a stronger ammonifying bacterium. This experience agrees with that of others that in many fermentations the natural mixed culture is more effective than the isolated pure cultures. The straight lines of these curves are evident.

I have only one plausible explanation for these lines. Instead of the point of inflection we have a straight line. The point of inflection is the moment where the organisms have reached their highest number. In the first curves, the activity of bacteria soon decreased after this point and the curve approached more and more the horizontal direction. In these last experiments with soil bacteria, the bacteria maintained their activity for quite a while after they had reached their highest number. The abundance of food in milk, cheese, and similar products made the bacteria less resistant to their own products than the scanty food of soil extracts.

This goes even so far that the bacteria in a poorer medium produce a higher final concentration of fermentation products. We have several experiments on record, e. g., the following with CO_2 production in dextrose solution in which $CaCO_3$ is in excess. This dextrose solution is inoculated with soil. The one series contained some potassium phos-

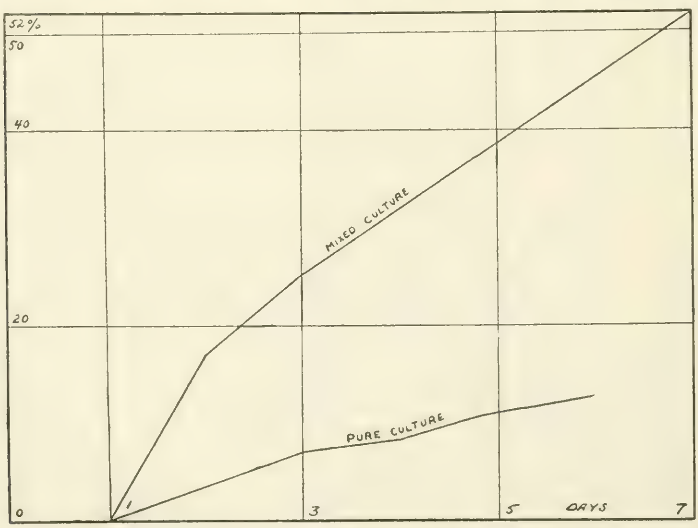


Fig. 15. *Ammonia Production in Peptone Solution.*

phate and asparagin, while the other one remained without any further addition (Rahn, Centralblatt f. Bakteriologie II, Bd. 20, p. 48).

CO_2 PRODUCTION IN DEXTROSE SOLUTION WITH Ca CO_3 AND SOIL.

	Soil.	2	3	4	5	6	7	8	9	10	11	12
No addition	moist	0	0	0	0.10	0.29	0.44	0.60	0.72	0.89	1.01	1.15
	dry	0	0	0.07	0.21	0.44	0.66	0.81	1.02	1.06	1.04	1.05
With Potassium, Phosphates and Asparagin	moist	0.07	0.17	0.28	0.42	0.52	0.62	0.70	0.76	0.78	......	0.79
	dry	0.22	0.33	0.41	0.51	0.60	0.69	0.71	0.75	0.73	......	0.74

The curve Fig. 16 shows the better nourished culture to be far ahead of the other culture for the first six days; but at the eighth day, they are alike and after that the culture without phosphate produces a good deal more CO_2 than the one with phosphates.

Figure 11, illustrating nitrification with and without dextrose, would probably give the same results if the experiment had been continued longer. At the end of 27 days, the soil with 0.5% dextrose is probably not very far from the maximum, as we can tell by the declining curve; the soil with 0.2% dextrose exceeds the first one a little; this may,

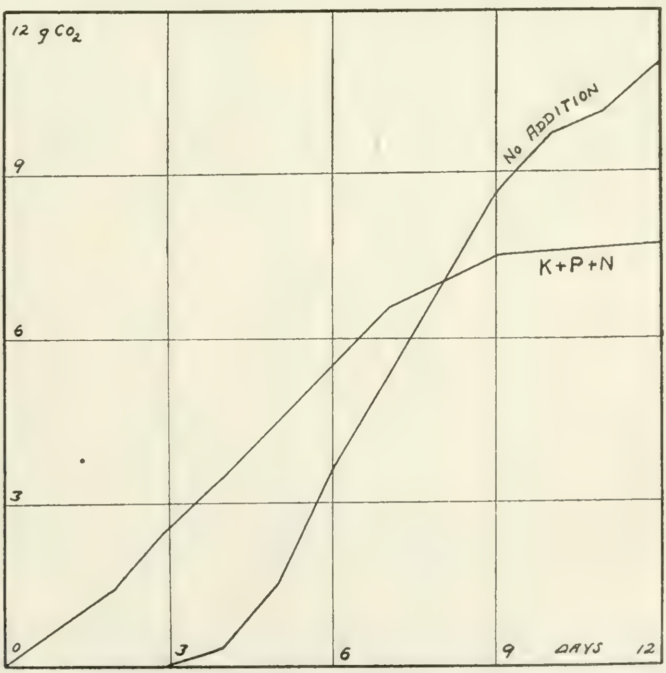


Fig. 16. *CO_2-Formation by Soil Bacteria with Plentiful and Scanty Food.*

however, be accidental, the difference being too small to prove anything. But the soil without dextrose just reaches the greatest rate of nitrification after 27 days, and it would probably within another week have exceeded the nitrate in the dextrose soils.

The general principle of these two experiments is so interesting and of so much significance especially to soil bacteriology, where we are dealing with very diluted solutions, that a test was made to ascertain the substances most concerned in this peculiar behavior of the cultures. The experiment was arranged in the following way: The following eight solutions were prepared, one liter of each:

Marked	O	1% peptone.
	K	1% peptone + 0.1% KCl
	P	1% peptone + 0.1% Na_2HPO_4
	Ca	1% peptone + 0.1% $CaCl_2$.
	KP	1% peptone + 0 1% KCl + 0.1% Na_2HPO_4.
	KCa	1% peptone + 0.1% KCl + 0.1% $CaCl_2$.
	PCa	1% peptone + 0.1% $CaCl_2$ + 0.1% Na_2HPO_4.
	KPCa	1% peptone + 0.1% $CaCl_2$ + 0.1% Na_2HPO_4 + 0.1% KCl.

100 cc. portions of these solutions were filled in liter-florence flasks and sterilized in the autoclave. After cooling, 10 grams of a sandy loam were put in each flask, and the amount of ammonia produced was determined in time intervals which seemed most appropriate to give an idea of the progress of ammonification. Much attention was paid to get the final ammonification. All flasks containing the potassium phosphate, had a sediment, but none of the others.

AMMONIA PRODUCTION IN PEPTONE SOLUTION WITH MINERALS.

Minerals added.	2 days.	3 days.	5 days.	7 days.	16 days.
O	21.7	47.1	95.4	99.9	98.3
	22.8	53.4	....	100.1	101.8
K	22.0	43.8	91.2	101.7	102.6
	23.1	67.3	93.8	104.8	106.0
P	27.2	68.6	84.1	95.0	90.4
	29.4	79.2	88.3	....	90.4
Ca	22.0	48.1	89.9	104.0	103.6
	22.0	50.8	94.1	97.3	105.4
KP	27.0	75.7	85.0	85.8	87.0
	33.4	....	89.8	91.8	87.3
KCa	22.0	53.7	90.6	101.0	102.0
	....	58.6	96.5	102.6	....
PCa	22.0	54.0	97.6	101.6	97.3
	22.5	63.1	98.0	103.0	101.8
KPCa	21.6	57.2	93.0	104.0	99.0
	23.1	62.4	94.2	106.0	99.4

These absolute results are recorded in another relative way in the following table. In all vertical columns, the ammonia in the solution without minerals is taken as a basis of 100, and the corresponding data of the other cultures are computed according to this base. This enables one to read directly the percentage increase or decrease.

AMMONIA PRODUCTION IN PEPTONE SOLUTION WITH MINERALS.

(Relative numbers with untreated soil = 100.)

Minerals added.	2 days.	3 days.	5 days.	7 days.	16 days.
O	100	100	100	100	100
K	101	110	97	103	104
P	127	147	90	95	90
Ca	99	98	97	100	105
KP	136	150	92	89	87
KCa	100	112	98	102	102
PCa	99	116	102	102	100
KPCa	100	119	98	105	99

After two days, we see all cultures alike except the two series with P and KP. These two are 27% and 36% ahead of the others. The favorable influence is due to the soluble phosphate, since it does not show in those flasks where phosphate and $CaCl_2$ were given at the same time. Those flasks with phosphates without calcium have a heavy scum, those with both phosphate and calcium a thin scum and those without any phosphates, no scum. After 3 days, these two cultures are even 47% and 50% ahead of the untreated cultures. After 5 days, however, we notice the contrary. The one has developed 10% less ammonia than the untreated, the other 8% less. After 7 days, the difference is the same and after 16 days the diminution is still more pronounced.

It seems from this and the other results that it is not so much the quantity of the fermentable material (dextrose or peptone, respectively)

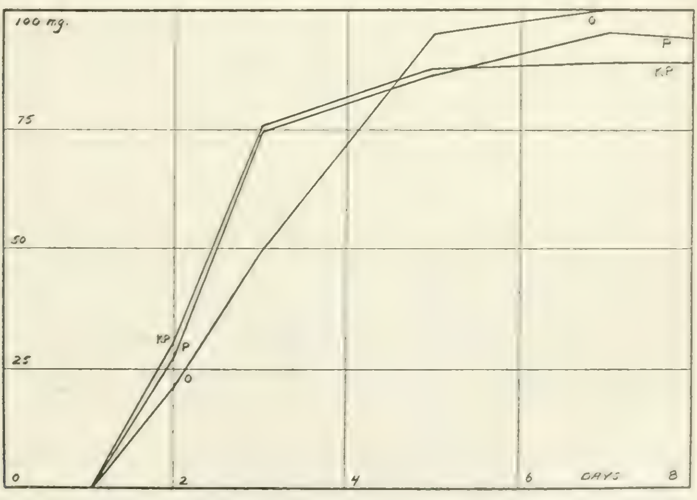


Fig. 17. *Ammonia Production in Peptone Solution with and without Minerals.*

but rather the amount of the "plastic food," i. e., of those substances used for building up the cell, that has the greatest bearing upon the final concentration of products. From these few results we can draw general conclusions, however.

This fact is evidently of great practical importance. Applications of this are made already in the vinegar fermentation. The German or quick vinegar process works with distilled diluted alcohol, which is practically free from nutrient substances, and yields a more concentrated vinegar than the French or Orleans process where wine, beer and similar alcoholic fluids with plenty of food material are fermented.

Could we not in the same way explain the rapid multiplication with very little fermentation by yeasts in aerated liquids? In the one case, they have plenty of one special food substance, namely oxygen, and there they ferment very little; in the other case, where this food supply is soon exhausted, they ferment much more completely.

The production of one certain compound may, however, depend upon other factors than the food supply only. Sackett, Patten and Brown (Mich. Exp. Station Bul. No. 43) noticed a much slower solvent action of bacteria upon bone meal in broth or peptone solution than in asparagin solution. This seems to be another example for better fermentation with poorer food, but the curves plotted from the data show that this is not the case. We have not, as in the other examples quoted, at first a stronger action of the better nourished bacteria, but the broth culture is lowest from the start. This indicates that in this case the varying food causes varying decompositions, probably there is some alkali produced in broth, neutralizing the soluble acid phosphates.

Fig. 18. Soluble Phosphates Produced in Different Media.

SOLUBLE PHOSPHATES FROM BONE MEAL.

Milligrams in 250 cc. Average of 10 bacteria.

Medium.	30 days.	60 days.	90 days.
Asparagin Solution	4.59	6.89	8.59
Peptone Solution	2.24	4.37	5.15
Beef broth	0.36	2.61	3.25

In this case, the curves prevent us from giving a wrong interpretation to the data of the above table.

Not only chemical products can be analyzed by their curves. The extensive experiments of Rubner (Archiv fuer Hygiene, Bd. 49, p. 355 and Bd. 57, p. 193) show that the formation of heat follows the same principle. Rubner measured the temperature of fermenting liquids by preventing with greatest care the radiation of heat. Thus the heat accumulated just like a chemical product of fermentation. The temperature curves look sometimes like fermentation curves, sometimes like enzyme curves. This latter type indicates a very large inoculation, so large, that the bacteria did not multiply materially; the constant active mass causes a curve of the enzyme type. The curves of Rubner on page 234 to 241 of vol. 57 of the Archiv fuer Hygiene show the heat production of B. coli in broth inoculated with 0.4 g., 2.4 g., and 5.6 g. of B. coli culture from potato. The first curve is distinctly microbial, the other two are of the enzyme type. Two other series of curves are also of interest, on page 230 and 232 of the same paper, the one demonstrating the microbial curves in the putrefaction of meat juice, urine and excreta of man and animals, the other showing the strictly enzymic curves of the autolysis of liver and muscle.

It seems tempting to decide by the method of curves whether the spontaneous heating of organic matter in hay stacks, in green corn and grain, in tobacco-bales, moist cotton-refuse, etc., is of microbial or purely chemical nature. However, the method fails here, because the chemical and microbial curve in this particular case would be of the same type. Namely, if the heat formation were due to a chemical process, this would produce a higher temperature after a certain time. The higher temperature would increase the rate of the chemical process, and more heat would be produced in the same length of time. This would cause a faster heating, which would result in a still more increased velocity, and so on. In short, we have in this case the type of an explosion, where the product accelerates the action. The continuously increasing velocity of the process would make it impossible to distinguish between a chemical and a microbial cause of the heat production.

It is hardly necessary to mention that the curve of a process will be an absolute means of discussion only in case of pure cultures. In natural fermentations, there is always the possibility that different processes taking place at the same time destroy the regular form of the curve. A simple example would be the growth of an acid-producing

and an alkali-producing organism in the same liquid. It is also possible that an enzymic curve under certain conditions shows the form of a fermentation curve. We can imagine that an enzyme is acting slowly at first, because of an unsatisfactory acidity of the medium. By a chemical or microbial process, independent of the enzymic action, the acidity may be made more suitable for the enzyme, and this will cause an increased rate of action of the enzyme and give the type of a fermentation curve without the presence of organisms. The value of the curves is, therefore, not an absolute one and no conclusions ought to be drawn without consideration of the possibilities of error.

CONCLUSIONS.

If a curve of a biochemical process is plotted, taking as abscissa the time elapsed and as ordinate the total amounts of compounds produced, the shape of this curve will in many instances indicate the nature of the change taking place. In a purely chemical or enzymic change, the active mass does not increase, and therefore the rapidity of the process measured by the angle of elevation of the curve does not increase. (An enzyme is understood to be a chemical compound, unable to multiply). The curve changes with the time, becoming gradually parallel to the base line. If we are dealing with changes caused by micro-organisms, the active mass increases as long as micro-organisms increase, and consequently, the rate of the process, or the angle of elevation will rise as long as the increase continues. This elevation of the curve is characteristic for compounds produced by any multiplying organism. From the time the increase ceases, we are dealing with a purely enzymic curve.

The exact plotting of the curve allows us to make fairly accurate statements about the multiplication and the duration of the increase of bacteria, even if they cannot be counted by our present methods. The point of inflection of a curve shows the moment when the organisms producing the substance under study reach their maximum number and can be studied with greatest convenience.

In some instances, the point of inflection is changed to a straight line, indicating a strain of bacteria very resistant to their own products; this seems to take place especially in poor media, as soil extracts. A few experiments indicate that poorly nourished bacteria are able to produce a larger amount of fermentation products than well nourished bacteria though they need a much longer time to accomplish it.

FOREWORD.

Technical Bulletin No. 6.

The importance of the lime-sulfur solution, both as an insecticide and fungicide is increasing each year. In many sections it is now the only remedy used against the scale insects and it is fast replacing Bordeaux mixture as a summer spray.

Many exceedingly interesting observations were made during the progress of the work here reported, for which, as yet, no satisfactory explanations have been reached. These will be taken up for further investigation as opportunity permits.

The methods of analysis used have made it possible to gain more information upon the composition of the polysulfides. In table V, page 10, it will be observed that the ratio between the mono-sulfide and polysulfide sulfur, in all but three cases, is almost exactly one to four, proving, in these cases at least, that the sulfide sulfur is in the form of calcium pentasulfide (CaS_5). In these cases the sulfur was in excess. In the three exceptions (2A, 2B and 6A) the limes used were comparatively pure and the calcium was in excess, making the formation of calcium pentasulfide impossible.

From these observations together with other unpublished results we are led to the conclusion that when the ratio between the calcium and sulfur is greater than 1 to 2¼ the sulfide sulfur is present as calcium pentasulfide. When a greater amount of lime is used the sulfide sulfur is present as a mixture of the lower sulfides together with some pentasulfide.

A. J. Patten.

LIME-SULFUR SPRAY.

BY JAMES E. HARRIS.

PART I

METHODS OF ANALYSIS.

The methods of analysis outlined in the following pages were developed preliminary to the investigations upon the manufacture and storage of the lime-sulfur spray reported in part II of this bulletin. The methods that have been in most general use are those described by Avery (1) and Haywood (2). These have been slightly modified from time to time by other investigators, but at best they are tedious of operation and time consuming.

Recognizing the need of improvement in the analytical methods, an attempt was made to modify them with the idea of securing greater accuracy and rapidity. The main differences between the methods herein described and those in common use lie in the manner of effecting the oxidation of the sulfur compounds and in the estimation of the mono-sulfide and total sulfide sulfur, and the length of time required to make a complete analysis of a sample of lime-sulfur solution is reduced from more than one day to only a few hours. This in itself is an important feature where a large number of analyses must be made.

In all of our work 25 cc. of the concentrated solution was diluted to 250 cc. and the following determinations were made:

(a) Total sulfur.
(b) Mono-sulfide sulfur.
(c) Thiosulfate sulfur.
(d) Sulfite and sulfate sulfur.
(e) Total sulfide sulfur.
(f) Calcium oxide.

A description of the methods follows:

Total sulfur.—As it is a well known fact that sodium peroxide is a very powerful oxidizing agent, it was substituted in our work for the usual oxidizing agents bromine water and hydrogen peroxide, and was found to give excellent results. The method of procedure is as follows: 10 cc. of the diluted solution is placed in a tall beaker, covered with a watch glass and five or six grams of sodium peroxide added. After standing a few minutes, hydrochloric acid is added with stirring until the solution clears up. If all the sulfur has not been oxidized, this will be indicated by a milky precipitate after the solution has been made acid. The addition of a little more sodium peroxide will complete the oxidation. In general however, five or six grams of sodium peroxide will be sufficient. After boiling a few minutes to drive off the dissolved gases, the sulfur may be precipitated as barium sulfate. This method of effecting the oxidation is more convenient and rapid than either the bromine

(1) Bulletin 90, page 104, Bureau of Chemistry.
(2) " 101, " "

or hydrogen peroxide method. The former is disagreeable to use and much time is consumed in evaporating off the excess bromine. The latter requires the use of hydrogen peroxide solution free from sulfates. Since it is very difficult to secure such a solution in the market, it must be prepared by allowing the solution to stand for some time in contact with barium carbonate, or the amount of sulfur in the hydrogen peroxide must be determined and deducted from the final result. Also when hydrogen peroxide is used some time must be spent in heating the mixture before acidifying with hydrochloric acid and precipitating with barium chloride. Since sodium peroxide free from sulfates is easily obtainable, the above method avoids all the inconveniences incident to the use of bromine water and hydrogen peroxide.

Comparative results for total sulfur using sodium peroxide, hydrogen peroxide and bromine as oxidizing agents:

TABLE I.

Oxidizing agent.	Wt. of $BaSO_4$.	Wt. of $BaSO_4$. corrected for S. in reagents.	Total sulfur in 100 cc. original solution.	Average.
	Grams.	Grams.	Grams.	
Sodium	2.3835	....	32.73	32.73
Peroxide	2.3837	....	32.73	
Hydrogen	2.4019	2.3829	32.72	32.735
Peroxide	2.4045	2.3855	32.75	
Bromine	2.3680	....	32.51	32.58
	2.3771	....	32.64	

Monosulfide sulfur.—The monosulfide sulfur was determined in this laboratory at first by the ammoniacal zinc chloride method, the only modification being the method of drawing test portions for determining the end point. These test portions were filtered by means of the apparatus devised by Knorr* for work in sugar analysis. The apparatus consists of a piece of glass tubing closed at one end by a piece of perforated platinum foil sealed into the glass. An asbestos pad is sucked into this and the test portion drawn through the pad. By inverting the tube a drop of the filtered solution may be added to the nickel sulfate on the tile. Even with this rapid method of filtering, it was found to be a long and tedious process to accurately determine the end point. Therefore an attempt was made to find some other method for determining the monosulfide sulfur. In titrating the solution of lime sulfur with iodine for the purpose of determining the thiosulfate sulfur according to the method described below, it was noticed that the yellow color of the solution disappeared when the same number of cc. of N/10 iodine had been used as were required of the decinormal zinc chloride solution to completely remove the sulfide from solution. This indicates that the reaction $CaSx+I_2=CaI_2+Sx$ goes to completion before the reaction between the iodine and calcium thiosulfate commences. This principle was therefore made use of in determining the mono-sulfide sulfur and the method was tried on a large number of samples containing varying

*Described in Principles and Practice of Agricultural Analysis. Wiley, Vol. III P. 130.

amounts of sulfide and thiosulfate sulfur, comparing it carefully with the results obtained using the ammoniacal zinc chloride method. The two methods were found to check nicely. With a little practice the end point can be determined more accurately with the iodine solution than with the ammoniacal zinc chloride. The white milk of sulfur separating out forms a good background for determining the point at which the yellow color disappears. This method avoids the laborious process of filtering test portions to determine the end point by means of an external indicator. Tarter[1] and Bradley endeavored to use the disappearance of color as an end point reaction with ammoniacal zinc chloride as the titrating agent but because of the yellow color of the zinc polysulfide, found it to be very unsatisfactory.

The following table shows a number of comparative analyses by the two methods, each analysis being given in duplicate. In each of these tests a 10 cc. sample of the diluted solution was used.

TABLE II.

Sample No.	By ammoniacal zinc chloride.		By N-10 iodine.	
	cc. used.	Per cent monosulfide sulfur.	cc. used.	Per cent monosulfide sulfur.
1. (a)	21.75	3.48	21.30	3.41
(b)	21.35	3.42	21.35	3.42
2. (a)	13.30	2.13	13.10	2.10
(b)	13.15	2.10	13.20	2.11
3. (a)	23.40	3.74	23.50	3.76
(b)	23.70	3.79	23.60	3.78
4. (a)	21.55	3.45	21.45	3.43
(b)	21.70	3.47	21.55	3.45
5. (a)	31.60	5 06	31.60	5.06
(b)	31.80	5.09	31.60	5.06

From the above table it will be seen that the general results by the two methods are in quite close agreement but the duplicates obtained using the iodine give better checks than those in which the decinormal zinc chloride was used. Where the sample is to be used for the thiosulfate sulfur determination, it is better to take 25 cc. of the diluted sample instead of 10 cc.

Thiosulfate sulfur.—The thiosulfate sulfur may be determined by using the same sample that has been used for determining the monosulfide sulfur. Therefore, after the end-point for the mono-sulfide has been reached we continue to add N/10 iodine until the characteristic blue color is obtained, starch solution being added as an indicator. This additional amount of iodine determines the amount of thiosulfate sulfur. In case this same sample is to be used for the determination of the sulfate and sulfite sulfur, it is better to leave out the starch solution and determine the end point by means of the colorizing effect of

(1) Journal of Ind. and Eng. Chemistry, Vol. 2, p. 271.

the iodine itself. The starch solution prevents the rapid settling of the sulfur precipitate.

Sulfate and sulfite sulfur.—As has been customary in the past, these have been determined together. After the titration with iodine for the monosulfide and thiosulfate sulfur the solution is allowed to stand until the sulfur settles. It is then filtered, acidified and the sulfate and sulfite (now sulfate) sulfur is precipitated in the cold.

*The total sulfide sulfur.**—This form of sulfur may be determined by placing the filter containing the sulfur that has been filtered off preliminary to the determination of the sulfate sulfur, in a beaker dissolving by heating with 25 cc. concentrated potassium or sodium hydroxide, oxidizing with sodium peroxide, as in the total sulfur determination, and precipitating and weighing as barium sulfate. However, as this is rather a long process, it has been customary to determine the sulfide sulfur by difference, that is by subtracting the thiosulfate, sulfate and sulfite sulfur from the total sulfur.

Calcium oxide.—The calcium oxide may be determined by drawing off 10 cc. of the diluted solution and oxidizing the sulfur exactly as in the total sulfur determination. After acidifying extra care must be taken to boil off all the gases in solution, for if any carbon dioxide is present a portion of the calcium will be precipitated as the carbonate upon making the solution alkaline. The solution after being boiled is made alkaline and filtered if a precipitate appears. The calcium may then be precipitated with ammonium oxalate in the usual way.

An estimation of the calcium oxide in solution may be had from the iodine titration. Tartar[1] and Bradley have shown that there is no cal-

* Since this manuscript was prepared, Mr. O. B. Winter of this laboratory has done a considerable amount of work on the determination of the sulfide sulfur by weighing the free sulfur separated out by the iodine titration. This was suggested by Tarter and Bradley but they recommended for more accurate results, dissolving the sulfur in potassium hydroxide and estimating in the same way as for total sulfur. This of course, means a much greater amount of work than where the sulfur is weighed directly.

The method of weighing the free sulfur gives slightly higher results than other methods and also more closely agreeing duplicates. A comparison of results by the two methods is here given

Sulfur by direct weighing. Grams.	Sulfur by dissolving and reprecipitating. Grams.
0.2015	0.1963
0.1834	0.1805
0.1835	0.1810
0.1509	0.1456
0.1882	0.1789
0.1526	0.1332

These differences may be explained in two ways, either some of the iodine is occluded in the free sulfur precipitate causing it to be too high, or on the other hand the barium sulfate precipitate may be slightly soluble in the solution containing rather high concentrations of potassium and sodium chloride, causing low results. Otto Folin, Jour. Biol. Chem., Vol. I, Nos. 2 and 3, shows that the presence of potassium chloride does give low results for sulfur. This was verified by determining the sulfur in 40 cc. of approximately N/5 H_2SO_4 in the presence of an excess of potassium.

(1) Journal of Ind. and Eng. Chemistry, Vol. 2, p. 271.

cium hydroxide present in the lime sulfur solution, so that the calcium is present as the sulfide and thiosulfate together with a little as the sulfate and sulfite. According to the reaction: $CaSx+I_2=CaI_2+Sx$, the amount of calcium oxide in solution as the sulfide is given by multiplying the number of cc. of N/10 iodine used in the monosulfide sulfur determination by 0.0028. According to the reaction $2CaS_2O_3+I_2=CaS_4O_6+CaI_2$, the amount of calcium oxide present in the form of the thiosulfate is determined by multiplying the number of cc. of decinormal iodine used in the thiosulfate determination by 0.0056. If there is any sulfate or sulfite sulfur present the corresponding amount of calcium oxide may be computed and added to the above. This method of estimating the amount of calcium oxide by computation was compared with the usual method in a series of fifteen experiments, and the results are given in the Table III:

TABLE III.

No. of sample.	cc. N-10 iodine used in monosulfide sulfur determination.	cc. N-10 iodine used in the thiosulfate sulfur determination.	Sulfate sulfite sulfur.	CaO by computation.	CaO Experimental value.	Difference.
1	13.5	4.25	.03	6.20	6.22	.02
2	17.15	5.65	none	7.97	7.97	.00
3	18.2	5.35	none	8.09	8.22	.13
4	18.05	5.25	.05	8.06	8.12	.06
5	20.15	5.95	.13	9.15	9.14	.01
6	15.50	4.30	.03	6.79	6.90	.11
7	15.80	6.35	.09	8.22	8.12	.10
8	25.20	7.70	.05	11.52	11.62	.10
9	13.20	4.50	.10	6.36	6.39	.03
10	26.3	5.55	.03	10.52	10.61	.09
11	23.4	6.25	.03	10.09	10.06	.03
12	20.4	5.70	.08	9.01	9.03	.02
13	21.55	6.75	.08	9.92	10.00	.08
14	13.65	4.20	.02	6.20	6.30	.10
15	47.1	3.75	.06	15.37	15.43	.06

Number.	Solution.	$BaSO_4$, grams.	Sulfur, grams.	Difference, grams.
1	Water	0.9373	0.1289	....
2		0.9385		
3	15 grams KOH, 5 grams Na_2O_2	0.9821	0.1260	0.0029
4	400 cc. H_2O	0.9158		

These results indicate that the method of weighing the free sulfur gives more nearly the correct result and in our later work this method has been used whenever a direct determination of the sulfide sulfur was desired.

It will be noticed that the greatest variation between the computed value and the determined value is 0.13% while in ten out of the fifteen values the variation is under 0.10%. The above determinations were made on 10 cc. samples of the diluted solution.

SUMMARY.

Total Sulfur.—The total sulfur is determined by oxidizing the sulfur present to the sulfate form, using sodium peroxide as the oxidizing agent and precipitating and weighing as barium sulfate.

Monosulfide sulfur.—The monosulfide sulfur is determined by titrating a 25 cc. sample of the diluted solution with decinormal iodine until the yellow color disappears. The number of grams per 100 cc. of the original solution is given by the computation. $\frac{\text{cc. iodine} \times .0016 \times 1000.}{25}$

Thiosulfate Sulfur.—The thiosulfate sulfur is determined by continuing to add iodine solution after the monosulfide end point has been reached until we have one drop in excess. This additional amount of iodine determines the amount of thiosulfate sulfur. For a 25 cc. sample the grams per 100 cc. of original solution is given by computation. $\frac{\text{cc. iodine} \times .0064 \times 1000.}{25}$

Sulfate and Sulfite Sulfur.—These are determined together by precipitation in the cold as barium sulfate after filtering off the sulfur from the solution used for the monosulfide and thiosulfate sulfur determinations.

Total Sulfide Sulfur.—This may be determined by dissolving the sulfur precipitate, filtered off for the sulfate sulfur determination, in concentrated potassium hydroxide, oxidizing and precipitating as barium sulfate.

Calcium oxide.—The calcium oxide may be determined by oxidizing the sulfur to the sulfate form and precipitating the calcium as the oxalate.

It may also be determined by computation from the amount of iodine used in the monosulfide and thiosulfate sulfur determinations and from the amount of sulfate and sulfite sulfur present. The following computation gives the number of grams per 100 cc.: (cc. iodine used for monosulfide sulfur) + (2 X cc. iodine used for thiosulfate sulfur) X $\frac{.0028 \times 1000}{25}$ + (sulfate and sulphite sulfur) X 1.75.

ADVANTAGES OF THESE METHODS OVER OLD METHODS.

1. The use of sodium peroxide as an oxidizing agent is more convenient than either bromine water or hydrogen peroxide and does not have to be especially prepared for the work as does the hydrogen peroxide solution.

2. The necessity of using the ammoniacal zinc chloride solution is avoided by substituting an iodine titration, thus doing away with the laborious task of filtering test portions for determining an end point by means of an external indicator.

3. The process of dissolving the zinc polysulfide sulfur or sulfur precipitate in order to determine the sulfide sulfur is done away with.

4. The titration of the solution with acid, preparatory to making the thiosulfate sulfur determination, is made unnecessary.

5. A method of determining the calcium oxide present by computation from the decinormal iodine used for the thiosulfate and monosulfide sulfur determinations and from the sulfate and sulfite present.

PART II

MANUFACTURE AND STORAGE OF HOME-MADE SOLUTIONS.

During the past year many demands were made upon the chemical division of the Experiment Station for some specific information on certain points in regard to the manufacture and storage of the lime-sulfur spray. As the literature of the subject did not furnish the desired information the investigations detailed in the following pages were undertaken.

No experiments were undertaken bearing upon the length of time the solution should be boiled as the experience of previous investigators on the subject has been that the maximum of sulfur in solution is obtained by boiling from 45 minutes to one hour.

EFFECT OF LIME ON THE COMPOSITION OF THE LIME-SULFUR SOLUTION.

In order to determine the value of the various limes found in the Michigan market, samples of lime-sulfur were made up from six brands of lime. With two exceptions, two batches were made up from each brand, one according to the formula, 60 pounds of lime, 125 pounds of sulfur and 60 gallons of water, and the second according to the formula 50-100-50, these being the formulae commonly used. The lime-sulfur was made up in barrel lots in a wooden tank built for the purpose, steam at 45 pounds pressure being used as the boiling agent. The solutions were boiled for one hour. Allowance was made for the condensation of the steam so that the lime-sulfur and water would be in the above mentioned proportions *at the finish*. The limes used were: 1. Kelly Island Lime. 2. A special low magnesia lime put out by the Michigan Lime Co. 3. Crescent Brand Lime. 4. Ohio and Western Co's Lime. 5. Kelly Island Lime and Transport Co's Lime from White Rock, Ohio. 6. Bay Shore Superior Lime.

These limes showed the following analyses for calcium oxide and magnesium oxide.

TABLE IV.

Sample.	CaO per cent.	MgO per cent.
1	65.70	31.13
2	96.40	0.13
3	74.70	22.47
4	69.22	28.87
5	57.66	41.97
6	86.77	10.21

After making up the solutions, samples were drawn off, filtered while hot, and after cooling were analyzed. The results of the analyses are given in Table V. The letters A and B in column 1 indicate the formula used, A for the 60-125-60 formula and B for the 50-100-50 formula. The results are expressed in grams per 100 cc. of the original solution.

TABLE V.

Sample.	Total sulfur.	Mono-sulfide sulfur.	Poly-sulfide sulfur.	Total sulfide sulfur.	Thio-sulfate sulfur.	Sulfate and sulfite sulfur.	Calcium oxide.	Density.	Density degrees Beaume.
1A........	18.00	2.92	11.40	14.32	3.42	none	8.22	1.1450	18.2
1B........	17.58	2.75	11.29	14.04	3.58	none	7.97	1.1410	17.8
2A........	24.61	4.28	15.72	20.00	4.61	.03	11.96	1.2170	25.7
2B........	21.08	3.73	13.44	17.17	3.87	.04	10.50	1.1860	22.6
3A........	19.96	3.26	12.96	16.22	3.66	.08	9.07	1.1650	20.4
3B........	20.55	3.27	13.08	16.35	4.20	none	9.63	1.1732	21.2
4A........	17.65	2.81	11.22	14.03	3.62	none	8.16	1.1401	17.7
5A........	13.65	2.18	8.80	10.98	2.67	.02	6.36	1.1021	13.3
5B........	15.54	2.52	10.16	12.68	2.83	.03	7.24	1.1110	15.4
6A........	20.93	3.49	12.44	15.93	4.06	.04	8.30	1.1994	21.8

Comparing the above two tables, it is found that in a general way the amount of total sulfur in solution varies inversely with the amount of magnesium oxide present in the lime used. If we arrange the above samples according to the amount of total sulfur present, we have them in the order 2, 6, 3, 1, 4, and 5. If we arrange them according to the amounts of magnesium oxide present in the lime, we have the order 5, 1, 4, 3, 6 and 2, which, with the exception of samples 1 and 4, is the above order reversed. Samples No. 1 and 4 are very nearly alike, both in the amount of sulfur in solution and in the amount of magnesium oxide present in the limes used, the variation being so small it is not strange that in the case of these two samples the order is not reversed. This may have been brought about by a slight variation in the amount of steam condensation in the two cases, this variation causing a corresponding variation in the concentrations.

This evident relationship between the amount of sulfur present and the percentage of magnesia in the lime might be due to a harmful effect of the magnesia or it might be due to the fact that when a definite formula is used, such as the 50-100-50 formula, the percentage of calcium oxide present is cut down in the exact ratio in which the magnesium oxide is present, thus reducing the efficiency of the lime.

From the above data no conclusion can be drawn as to which of the formulae used is the better. In each, since the lime is never pure calcium oxide, the sulfur is in excess. In some cases it is found that formula A gives better results, in others formula B. These variations (which are small) are probably due to variations in the amount of steam condensation. If one of the formulae is to be used the 50-100-50 formula is less expensive and gives as good results as the 60-125-60. Later in the paper however, a recommendation will be given as to the

proportions of lime and sulfur to be used, the proportion to be determined by the purity of the lime.

EFFECT OF MAGNESIA ON THE COMPOSITION OF LIME-SULFUR SOLUTION.

These samples of lime were used showing the following analysis.

TABLE VI.

	CaO per cent.	MgO per cent.
1. Kelly Island Lime	74.4	22.5
2. Bay Shore Superior Lime	86.8	10.2
3. Baker and Adams Lime (From Marble)	99.0	1.0

From each of the first two lines, two samples of lime-sulfur were made up, the first according to the formula 100 grams lime, 200 grams sulfur and 800 grams water. In the second sample in each case, the amount of lime was increased so that there was half as much calcium oxide as sulfur, the amount of water remaining the same. From the third lime, only one sample was made up and this in such quantities that the ratio of calcium oxide to sulfur was one to two. Each sample was boiled for one hour in a flask under a reflux condenser, filtered while hot, allowed to cool and analyzed. In the following table the results, for the sake of more accurate comparison, are given in actual percentage instead of grams per 100 cc. of solution as in the first experiment.

TABLE VII.

Lime used.	Formula.	Total sulfur.	Mono-sulfide sulfur.	Total sulfide sulfur.	Thio-sulfate sulfur.	Sulfate and sulfite sulfur.	Calcium oxide.	Density.	Density degrees Beaume.
1A	100-200-800	17.34	2.84	14.06	3.29	none	8.02	1.1680	20.7
1B	135-200-800	18.40	3.24	14.82	3.57	.01	9.00	1.1941	23.4
2A	100-200-800	17.75	2.96	14.28	3.44	.03	8.30	1.1794	21.8
2B	115-200-800	18.42	3.42	15.63	2.78	.01	8.44	1.1822	22.1
3D	101-200-800	18.60	3.25	15.28	3.37	.03	8.85	1.1930	23.4

From column 3 it will be seen that the amount of total sulfur in solution in samples 1B, 2B and 3B, in all of which the ratio of calcium oxide to sulfur is as one to two, is very nearly the same, the greatest variation being 0.2% between 1B and 3B. The greatest variation in these three samples in which the calcium oxide and sulfur are in the above ratio occurs in column 5, under the head of Total Sulfide Sulfur. The variation between 1B and 2B is 0.8%. This variation cannot be ascribed to the fact that there was less magnesia in sample 2 than in 1, because in sample 2 we find a larger amount of sulfide sulfur than in 3, which is much lower in magnesia. From these results we must conclude that the magnesium oxide present does not effect the amount of sulfur going into solution providing enough of the lime is taken so that

we may have half as much *calcium oxide* as of sulfur. The magnesium oxide is harmful however, because of the fact that it separates out in the form of a slime. From the above results it would seem best not to stick to any one formula in making up the lime sulfur solutions, but to obtain from the lime company, an approximate analysis of the lime to be used, and take an amount such that the calcium oxide and sulfur may be in the ratio of one to two.

EFFECT OF STORING THE SOLUTION IN CONTACT WITH THE SEDIMENT.

To determine the effect of allowing a lime-sulphur solution to stand in contact with its sediment, a number of samples of lime-sulfur were made up, analyzed, and allowed to stand for periods varying from four to seven weeks and again analyzed.

TABLE VIII.

Sample.	Time allowed to stand.	Total sulfur.	Mono-sulfide sulfur.	Total sulfide sulfur.	Thio-sulfate sulfur.	Sulfate and sulfite sulfur.	Calcium oxide.	Density.	Density degrees Beaume.
1A........	0 weeks..	18.00	2.92	14.32	3.42	none	8.22	1.1450	18.2
1B........	6 weeks..	17.36	2.89	14.00	3.36	.04	8.12	1.1416	17.9
1C........	7 weeks..	16.40	2.40	11.73	4.57	.10	8.13	1.1466	18.4
2A........	0 weeks..	17.58	2.75	14.04	3.58	none	7.95	1.1410	17.8
2B........	6 weeks..	16.83	2.78	13.63	3.20	.03	7.84	1.1385	17.6
2C........	7 weeks..	16.62	2.53	12.54	4.20	.09	8.12	1.1435	18.1
3A........	0 weeks..	24.61	4.28	20.00	4.61	.03	11.96	1.2170	25.7
3B........	6 weeks..	21.05	4.20	17.53	3.50	.03	10.64	1.1910	23.1
3C........	7 weeks..	24.34	4.04	19.39	5.00	.05	11.62	1.2180	25.8
4A........	0 weeks..	21.08	3.73	17.17	3.87	.04	10.50	1.1860	22.6
4B........	5 weeks..	20.30	3.62	16.26	4.00	.04	10.20	1.1786	21.8
4C.	6 weeks..	21.02	3.74	16.71	4.25	.06	10.30	1.1878	22.8
5A........	0 weeks..	19.96	3.26	16.22	3.66	.08	9.07	1.1650	20.4
5B........	5 weeks..	19.33	3.22	15.58	3.62	.13	9.25	1.1630	20.2
6A........	0 weeks..	20.55	3.27	16.35	4.20	none	9.63	1.1732	21.2
6B........	4 weeks..	20.59	3.38	16.61	3.95	.03	9.46	1.1715	21.1
7A........	0 weeks..	13.65	2.18	10.98	2.67	.02	6.36	1.1021	13.3
7B........	4 weeks..	13.31	2.18	10.68	2.60	.03	6.22	1.0998	13.0
7C........	5 weeks..	13.43	2.11	10.45	2.88	.10	6.40	1.1051	13.6
8A........	0 weeks..	15.54	2.52	12.68	2.83	.03	7.24	1.1110	15.4
8B........	4 weeks..	15.44	2.48	12.65	2.76	.03	6.90	1.1195	15.4
8C........	5 weeks..	15.53	2.48	12.62	2.88	.03	7.08	1.1221	15.7

For the sake of comparison, a like process was carried out, with filtered portions of each sample. The analyses 1A, 2A, etc., are the analyses of the original solutions. 1B, 2B, etc., are the analyses of the solutions that have stood in contract with the sediment. 1C, 2C, etc., are the analyses of the corresponding filtered solutions. Samples 1, 3, 5, and 7 were made up according to the formula 60-125-60 and the samples 2, 4, 6, and 8 according to the formula 50-100-50. The results are given in grams per 100 cc. of solution. See table VIII on opposite page.

A number of interesting observations may be drawn from the study of the above table. First, with the exception of samples 6B and 8C the amount of total sulfur in solution decreased both in the sample standing in contact with its sediment and in the filtered sample. In case of the two exceptions mentioned, the amount of total sulfur in solution remained constant; with a few exceptions, the amount of decrease in the other samples was small. Second, in all except the first two samples the filtered solution was found to have a greater concentration than the unfiltered. There is however, only a slight variation in favor of the filtered solution, except in samples 3B and 4B. These latter variations may be easily explained. A portion of the liquid was removed from each of the two barrels containing these solutions for use by the Horticultural Department, thus leaving a large air space over the liquid. In the first sample, the filtered solution was found to be much weaker than the unfiltered solution. This is explained by the fact that the glass stopper of the bottle containing the filtered solution did not fit tightly thus allowing the solution to be more or less exposed to the air. These results confirm the conclusions of other experiments, viz.: that the lime sulfur solutions should be stored in containers that will leave the solution as free as possible from the action of the air. Third, it is found on examining the columns headed monosulfide sulfur and total sulfide sulfur that the changes follow in a general way the changes noticed in the total sulfur column. There is, however, a much larger proportional falling off in the monosulfide and total sulfide sulfur in the filtered samples than in the unfiltered samples. For example, take sample 2, in the total sulfur column we find a falling off of 0.7% in the unfiltered solution and 0.9% in the filtered. These quantities are 4.0% and 5.1% respectively of the total sulfur in the original solution. In the monosulfide column, we find a slight gain in the unfiltered solution and a decrease of 0.22% in the filtered solution. This decrease being about 8.0% of the sulfide sulfur in the original solution. In the total sulfide sulfur column there is a dropping off of 0.41% in the unfiltered solution and 1.60% in the filtered solution, these quantities being respectively 2.9% and 11.4% of the amount of sulfide sulfur in the original solution. On examining the thiosulfate sulfur column we find that the changes here *do not* follow the changes in the total sulfur column. With the exception of 4B we find a *decrease* in the amount of thiosulfate sulfur in the unfiltered solution as compared with the original, while in the filtered solution we find an *increase*. This would indicate that in the unfiltered solutions the decrease in total sulfur goes on at the expense of the thiosulfate sulfur, while in the filtered solutions it goes on at the expense of the sulfide sulfur. The small decrease in the amount of the sulfide sulfur in the unfiltered solution may be due to an interaction between the thiosulfate sulfur and the sulfur in the sediment, a part of the thiosulfate sulfur being reduced to the sulfide form. It is of

interest to note that there was quite a large excess of sulfur used in making up each sample except in the case of No. 4. In No. 4 the formula 50-100-50 was used and since the lime used in this case was 96.4% pure calcium oxide the excess of sulfur was small. Sample No. 4 was the only one in which there was not a decrease in the thiosulfate sulfur in the unfiltered solution.

The second of the above three observations would lead us to conclude that there is no marked advantage to be gained from filtering the solution before storing. The third observation would lead us to conclude that if, as many experimenters maintain, the value of the solution depends upon the amount of sulfide sulfur present, it is better in those cases where an excess of sulfur has been used in making up the solution to allow it to stand in contact with its sediment.

EFFECT OF RE-HEATING THE SOLUTION BEFORE USING.

H. L. Fulmer[1] of the Ontario Agricultural College advises that the lime sulfur solutions which have been allowed to cool should be reheated before using. In determining the advantage to be gained in reheating the samples before using, samples 3, 4, and 8 of the above experiment were used. In sample 3 and 8 the excess of sulfur in the sediment was large; in sample 4 the excess of sulfur was small. The analyses corresponding to the numbers 3B, 4B, and 8B are the same as given under the same numbers in the preceding table and represent the analyses of solutions that have stood for some time in contact with the sediment. The analyses corresponding to the numbers 3D, 4D and 8D are analyses of the same samples that have been re-heated nearly to boiling in contact with the sediment, filtered while hot and analyzed.

TABLE IX.

Sample.	Total sulfur.	Mono-sulfide sulfur.	Total sulfide sulfur.	Thio-sulfate sulfur.	Sulfate and sulfite sulfur.	Calcium oxide.	Density.	Density degrees Beaume.
3B........	21.05	4.20	17.55	3.50	.03	10.64	1.1910	23.1
3D........	21.35	4.21	17.77	3.55	.03	10.61	1.1936	23.4
4B........	20.30	3.62	16.26	4.00	.04	10.20	1.1786	21.8
4D........	20.63	3.73	16.59	4.00	.04	10.07	1.1831	22.2
8B........	15.44	2.48	12.65	2.76	.03	6.90	1.1195	15.4
8D........	15.42	2.45	12.32	3.05	.05	6.93	1.1185	15.3

In samples 3 and 4 it will be noticed that there is a slight increase in the amount of total sulfur in the solution that has been re-heated, practically all the increase being in the sulfide sulfur. In sample 8 there is a slight increase in the thiosulfate sulfur and a corresponding decrease in the sulfide sulfur making the total sulfur in solution about the same as in the solution that has not been heated. From the above table

1 Bull. 177 Ontario Agr. College.

we may conclude that in those solutions in which the formula 50-100-50 or 60-125-60 is used, thus insuring an excess of sulfur, that there is but very little advantage to be gained from re-heating the solution before using.

SUMMARY.

1. If formula 50-100-50 or 60-125-60 or any other formula providing for an excess of sulfur is to be used, the lower the amount of magnesia in the lime used, the greater the amount of sulfur to go into solution.
2. If an analysis of the lime used is available an amount of lime should be used so that there shall be twice as much sulfur as calcium oxide. It is only in this way that a maximum amount of sulfur can be made to dissolve.
3. There is no particular advantage to be gained by filtering the lime sulfur solutions before storing. While there is a slightly greater dropping off in the *total* sulfur in the unfiltered solution than in the filtered, there is a smaller decrease in the *sulfide* sulfur in the unfiltered than in the filtered, provided an excess of sulfur has been used in the manufacture of the solution.
4. In those solutions, in the manufacture of which an excess of sulfur has been used, only a very slight increase in the amount of total sulfur in solution is observed when the solution is re-heated before using. This increase is not sufficient to pay for the cost of such an operation.

FOREWORD.

Technical Bulletin No. 7.

This bulletin forms a report of the continuation of the work outlined in Technical Bulletin No. 4.

Some definite information is given upon the composition of the organic matter of peat soils and two individual compounds, present in considerable quantities, have been isolated.

It is proposed to continue the study of the composition of the organic matter of soils in respect to nitrogenous substances, and to supplement the laboratory work with pot experiments conducted in the open fields. It is hoped that the application of the laboratory results may, later, be extended to larger experimental plots and finally be adopted as general farm practice.

ANDREW J. PATTEN.

ORGANIC NITROGENOUS COMPOUNDS IN PEAT SOILS. II.

INTRODUCTION.

To the Michigan farmers the peat and muck beds of the state have for a long time presented great possibilities as cheap and convenient supplies of nitrogen for fertilizing purposes. Being in many cases worthless for cultivation and containing considerable quantities of plant food, it would, at first sight, seem reasonable to suppose that they would form an ideal source of supply for this material. These beds are of such widespread occurrence that the majority of farms in this part of the country contain more or less extensive areas of them, while in almost all portions of the state large tracts of swamp land are found which are practically worthless for other purposes.

The amount of nitrogen usually varies from one and one-half to three per cent. of the air-dried material, or from about two to five-tenths per cent. of the material as it comes from the bog. When one considers that this is equivalent to from three to six tons of free nitrogen, eighteen to thirty-six tons of nitrate of soda or fourteen to twenty-eight tons of sulfate of ammonia per acre-foot, it becomes evident that such a natural product, could it be utilized, would be of no small value to the agriculturists of the state.

However, the mere fact that a substance contains nitrogen is no certain indication that it will be valuable as a fertilizer. Thus the atmosphere itself contains millions of tons of free nitrogen but this is useless as food to all but a very few plants, while scrap leather and a large variety of other products contain considerable quantities of nitrogen united with other elements in such a way as to be of equally small value for fertilizer. Saltpetre and sulfate of ammonia, on the other hand, have their nitrogen so combined that it can be readily utilized as plant food. Unfortunately the nitrogen in peat is in the former condition, and plants find difficulty in assimilating it when it is applied to the soil in the raw state and, as a result, what at first sight appears to be very valuable to the farmer has in reality proved to be of small value.

But it is possible, that by studying the various combinations in which nitrogen occurs in peat, some method of treatment may be devised by which it can be converted into forms more available for plant use. It is in the hope of throwing some light upon the character of these nitrogenous compounds and perhaps in this way rendering possible the discovery of some method for making them useful for fertilizing purposes that the present series of investigations has been undertaken. That the study of the decomposition products of peat offers one of the best ways of attacking the problem can scarcely be questioned, for it is really from these bodies that we must expect results when the

material is applied to the soil. Also it is by the study of the simple elementary units that we can best hope to attain a knowledge of the complex structure from which they are derived. In fact it is because of the failure of the earlier investigators to isolate and study individual chemical compounds among the mass of decomposition products, that we know so little of the possibilities of peat as a fertilizer.

Sources of Nitrogenous Material in Peat.

Some indications of what compounds may be expected to occur in peat can be gained from a study of its origin. The nitrogenous matter in peat may be derived from three sources, (1) the nitrogenous constituents of plants, which form the largest and most important source; (2) the remains of insects and other animals[1]; and (3) the remains of lower organisms such as moulds and bacteria. Schreiner and Shorey[2] say in regard to these: "It is usual to consider the organic matter of both plants and animals as made up of protein, and carbohydrates, but in addition to these elements there are, particularly in plants, a host of other compounds not included in these groups and which are a source of no small part of the soil organic matter. Among these are resin, hydrocarbons and derivatives, waxes, alkaloids, glucosides, tannins, phenols and their derivatives, acids, aldehydes, etc."

Much work has been done upon the nitrogenous constituents of plants and from the results of this work we may reasonably anticipate some of the compounds to be looked for in peat. Proteins are usually given the most prominent place among such organic nitrogenous bodies, partly, perhaps, because of the great scientific interest which at present centers around these bodies, and partly because the decomposition products of protein are, on this account, better known and more easily isolated than non-protein nitrogenous compounds. The compounds which we would look for from this source would be the mono and di-amino acids, prolin, and possibly polypeptides.[3] As will be shown later, most of the known amino acids have actually been isolated from the decomposition products of soil humus. Schreiner and Shorey[4] have demonstrated theoretically the possibility of the formation of pyridine compounds from the decomposition of protein and have isolated such a compound from soil. Such compounds would also be expected from the decomposition of plant alkaloids. Alkaloids themselves might also be present. Among the other non-protein nitrogenous compounds which might be expected are cholin, betain and other decomposition products of lecithins and certain nitrogenous glucosides.

From animal remains would come the usual protein decomposition products. As has been shown by several workers, chitin may form one of the sources of nitrogen in peat and humus. From the work of Ledderhose[5] glucosamine is a decomposition product of this material. From moulds and bacteria protein decomposition products would also be formed.

Reasoning on this basis, we should expect a large part of the nitrogen

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[1]J. J. Fruh, "Uber Torf und Dopperlite," Zurich, 1883. (Abs. in Jahresber. Fort. Ag. Chem., 1884, p. 17.)
V. Ollech. "Uber den Humus und seine Beziehungen zur Bodenfruchbarkeit," Berlin, 1890. (Abs. in Jahresber. Fort. Ag. Chem.)
[2]Bul. 53, Bureau of Soils, U. S. Dept. of Agriculture, p. 9.
[3]See Schulze, Vers. Stat. 73, 56 (1910).
[4]Bul. 53. p. 32, Bureau of Soils, U. S. Dept. of Agriculture, (1909).
[5]Zeit. Physiol, Chem. 2, 213.

of peat and humus to be present in the form of protein or its decomposition products. Protein bodies themselves are readily destroyed by bacteria and some of the resulting substances contain nitrogen in a form that is easily absorbed by plants. Were all the nitrogen in peat in this form, it would seem highly probable that peat would be very efficient as a nitrogenous fertilizer. As is well known, however, such is not the case, which might indicate that during the progress of decay either the protein bodies have been decomposed and to a large extent removed or have been so changed as to render their nitrogen unfit for plant food. While several amino acids have actually been isolated from peat, still in most cases the largest part of the nitrogen seems to consist of non-protein bodies, the chemical nature of which cannot as yet even be surmised.

It might seem, from the above discussion, that the isolation of these bodies should cause but little trouble, but in reality it has not proved so, and only within the last few years has the isolation of an individual organic nitrogenous compound been accomplished.

Previous Investigations.

One cannot help but be impressed with the amount of time which has been vainly spent in attempts to isolate some such compound in the pure condition. For years chemists have been extracting peat soils with alkali, precipitating from such extracts by means of acids, dark-colored amorphous substances, analyzing them, and claiming for them the characteristics of definite chemical compounds. So weak have been the foundations of these claims that until very recently none has stood the tests of later investigation. Perhaps the most noticeable feature about the experiments has been the uniformity of the general method of procedure by which each successive investigator has attacked the problem. By far the greater part have treated the soil with a solution of alkali or alkaline carbonate, precipitated from this solution the characteristic dark brown, flocculent substance, and then either analyzed this directly or first purified it by resolution and reprecipitation with acid or some arbitrary precipitant, such as lead acetate. The result has invariably been the same, a substance whose percentage composition differed from all of its predecessors and one which later investigators could not duplicate. Rarely were the researches carried beyond the ultimate analyses of these substances or their socalled salts, as the precipitates which they formed with various metallic salts were supposed to be. Until quite recently, few experiments were made from which any conclusion could be drawn as to the structural composition of the substances in question. They were simply nitrogenous compounds, if compounds they were at all, and, until the last twenty-five years but little attention was paid to the nitrogen radicle, although from the standpoint of agricultural utility this is of the highest importance. During the last few years, however, the study of the nitrogenous compounds of peat and humus has been carried on in a more scientific manner and we may safely say that more progress has been made than during the entire preceding history of the work.

The first worker to study the subject of peat humus was Einhof.[1]

[1] Neues allgemeines Journ. d. Chem. 6, 381 (1805). Gmelins' Handbook of chem., trans. by Watt, 1866, p. 459.

He was soon followed by Proust, Braconnot, Sprengel, and Mulder. Mulder was the most prominent. The work of all of them was, however, characterized by the same empirical methods which were in vogue at the time and which, as might be expected at this period of the development of organic chemistry, gave no insight into the nature of the nitrogenous substances present. In fact it was an open question at this time whether or not humus compounds really contained nitrogen except as an impurity. Mulder, while he seemed to hold plant protein as responsible for the presence of nitrogen, argued that it was present in the form of ammonia or ammonium salts. Detmer,[1] however, decided differently, finding the nitrogenous compounds of the soil to be very stable. He obtained his humus as usual by digesting with alkali. After precipitating with acid, he redissolved it in ammonia and precipitated the mineral constituents with phosphoric and oxalic acids and ammonium sulfide. When he had washed out the silica with hydrochloric acid he obtained an ash-free substance containing one and five-tenths per cent. of nitrogen. No ammonia was evolved upon making alkaline, but about twenty-one per cent. of the total nitrogen was removed by treatment with nitrous acid. This seems to be the first tangible evidence of the presence of any particular nitrogen group in humus. But although in the light of modern work this point assumes great importance, it seems to have attracted but slight attention then. Two years afterwards he also decided that humic acid could be prepared free from nitrogen. Simon[2] claimed that peat absorbed nitrogen from the air with the formation of ammonium compounds, a fact which was later disproved. Ritthausen[3] attributed the high nitrogen content to the formation of complex, difficulty decomposable materials by the absorption of ammonia and pointed to the low ammonia content as an indication of it, claiming that after absorption it was not present as such. v. Sivers,[4] in attempting to disprove Ritthausen's theory, found that he could drive off only small amounts of ammonia by heating with potassium hydroxide. He decided that all ammonia taken in remained there as such, i. e. did not go to form complex compounds. He held that most of the nitrogen was in the protein form but offered no conclusive evidence. Grouven,[5] in trying to show that the nitrogen of humus was due to the absorption of ammonia by humic acids, found that in various samples only one-fiftieth of the total nitrogen was given up when heated several hours with milk of lime and only one-twentieth when heated two hours with potassium hydroxide.

Such was the state of affairs up to the year 1887. Not only had no individual organic nitrogenous compound been isolated but, with the exception of Detmer's experiment with nitrous acid, neither was anything of a definite nature known regarding the general form of the nitrogen radicle. Even this experiment seems to have passed unnoticed and to have had no influence upon subsequent work. The treatment of humus compounds with alkali had been with the view of determining the presence or absence of ammonia alone. During the year 1887, how-

[1]Vers. Stat. 14, 248 (1871).
[2]Bied. Cent. Bd. 8, (1875). Jahresber. Fort. Ag. Chem. 18, 6.
[3]Fühlings Landw. Zeitung 1877, 161; see Vers. Stat. 25, 169, (1881).
[4]Vers. Stat. 24, 183, (1880).
[5]Fühlings Landw. Zeitung 1883, p. 391. Abs. in Jahresber. Fort. Ag. Chem. 1883, 19.

ever, two articles appeared which took up the subject from another standpoint. A. Baumann[1] found that certain black Russian soils, rich in humus, containing but traces of ammonia, as such, yielded a considerable amount of it upon heating with dilute hydrochloric acid or upon treatment with alkali even in the cold. He pointed out that such conduct might be due to the presence of amino and amido compounds. Almost simultaneously this subject was taken up somewhat more extensively from this point of view by Berthelot and Andre[2] in the course of their work on amides. They found that boiling with acids, alkali or even water split off ammonia from humus. They, too, attributed this to the presence of amides. A short time after this, Warington[3] showed the presence of small amounts of amino nitrogen in a sample of Rothamsted soil which, however, had been heavily manured. He used both nitrous acid and hypobromite in his work. The presence of any considerable amounts of amides was later contradicted by Sestini,[4] who stated that he could remove only small amounts of ammonia by boiling with alkali. As there is probably considerable difference in the composition of humus and peat from different sources, this could hardly be considered conclusive evidence that such materials might not in some cases contain considerable amido nitrogen. As has already been shown, several experimenters failed to find nitrogen in peat and humus which could be removed by treatment with alkalies. In some cases at least, this was probably due to the breaking down of the amides in the preliminary extraction of the humus material from the soil. Sestini also demonstrated the presence of amino nitrogen by the action of nitrous acid and, as had Berthelot and Andre, suggested the presence of amino acids. Likewise, Dojarenko[5] found considerable quantities of amino nitrogen in certain Russian soils rich in humus. Unlike the other investigators, he determined the amount present quantitatively, using Sachsse and Kormann's method as modified by Boehmer.[6] He extracted the soil with ten per cent. sodium carbonate and worked with the "humic acid" thus obtained. He found from twenty-two to seventy per cent. of the total nitrogen in this to be in the amino form, from five to twelve per cent. in the amido form, while the ammonia varied from seventy-eight hundredths to two and thirty-six hundredths per cent. The ammonia was determined by distillation with magnesium oxide, and the amido nitrogen by converting into ammonia by boiling with dilute hydrochloric acid and subsequent distillation with magnesium oxide. He assumed all of the amino nitrogen to be present in the form of amino acids. Some years later Shorey[7] applied some of the methods of protein analysis to the study of soil organic matter. He pointed out that, even though we might know much concerning the constitution of the compounds comprising the various groups isolated from protein by this system of analysis, we know nothing concerning their composition when isolated from soil. Three years later Jodidi[8] attempted to separate the mono- and di-amino acids in extracts of peat, using phospho-tungstic acid. As Shorey had pointed out, however,

[1] Vers. Stat. 33, 247 (1887).
[2] Comp. Rend. 103, 1101; Ann. Chem. 10, 368.
[3] Chem. News, 55, 27 (1887).
[4] Vers. Stat. 51, 153 (1899); L'Orosi 21, 1. Abs. in Exp. Sta. Rec. 10, 424 (1898).
[5] Vers. Stat. 56, 311, (1902).
[6] Vers. Stat. 28, 247, (1882).
[7] Rept. of Hawaii Ag. Exp. Sta. 1906, p. 50.
[8] Journ. Am. Chem. Soc. 22, 396 (1910). Mich. Ag. Coll. Exp. Sta., Tech. Bul. No. 4, p. 28.

while the compounds separated by this reagent in the case of protein consist of mono- and di-amino acids, it does not follow that such is true in the case of soils. Phospho-tungstic acid precipitates diamino acids from acid solution, leaving the monoamino acids dissolved. While it would undoubtedly act the same whether these acids were derived from animal protein or peat, still, in the latter case, other nitrogenous compounds might be present which would also be precipitated, thus increasing the amount of nitrogen classed as diamino nitrogen. Neither would all of the nitrogenous compounds remaining in solution be necessarily mono-amino acids. Jodidi also determined the quantities of amido and ammoniacal nitrogen. He concluded from his work that, in the peat which he used, the ammoniacal nitrogen amounted to but a few thousandths of one per cent. He says: "The bulk of the organic nitrogen, namely two-thirds to three-fourths, calculated upon the nitrogen in solution by boiling with acids, is present in the form of mono-amino acids, about one-fourth in the form of amides and the rest of the nitrogen represented diamino acids."

The actual isolation of an individual organic nitrogenous chemical compound from soil was first accomplished by Shorey.[1] He extracted the soil with cold alkali, acidified the extract, filtered and neutralized the filtrate with sodium hydrate, filtered and concentrated. From this concentrated solution a pure white crystalline compound separated which had the percentage composition, melting point and other characteristics of piccoline carboxylic acid, a true chemical compound whose properties and structural composition were well known. From his method of obtaining this substance, Shorey decided that it was present in the soil as such and was not a decomposition product formed in the laboratory during the process of extraction. He showed that it did not aid in the growth of plants and was, in fact, harmful to them. While the soil with which he worked was not a peat, nor even a muck soil, still the compound which he obtained was no doubt formed from decomposed organic matter of much the same sort from which peat is produced.

The following year Suzuki[2] published researches which gave the first definite knowledge of the individual amino compounds formed in the decomposition of soil organic matter. He worked with three samples of humic acid, one obtained from Merck, one prepared from a soil and one from a compost. He found only small quantities of amino acids present as such, but on boiling with concentrated acid and separating by the Fisher esterification method he obtained from five hundred grams of dry humic acid, 2.39 g. alanin, 2.16 g. leucin, 0.11 g. alanin +amino valeric acid, 0.57 g. of amino valeric acid, 0.67 g. of copper salt of active prolin, 0.06 g. of aspariginic acid, 1.9 g. of ammonia and 30.3 g. of the copper salts of unidentified acids. Glutaminic acid was also found together with traces of histidin and tyrosin. As these compounds are typical decomposition products of protein, he concluded that the nitrogen of humic acid is in the form of a complex protein body.

The latest work at hand on this subject is by Schreiner and Shorey.[3] They have succeeded in isolating from soils, histidin and arginin, two

[1]Rept. of Hawaii Ag. Exp. Sta. 1906, p. 37.
[2]Bul. Coll. of Agric., Tokyo, 7, 513. Abs. in Chem. Cent. 1907, Vol. 2, p. 1650.
[3]Bull. 74, p. 31, Bureau of Soils, U. S. Dept. of Agric. (1910)

of the hexone bases, as well as three other compounds of more complex structures, namely, cytosine, xanthine and hypoxanthine. The three last differ considerably from any of the substances previously discovered in soils and account for some of the non-protein nitrogenous compounds of hitherto unknown constitution.

Owing to the fact that some investigators have worked with humic acids while others have used the peat or soil itself, it is impossible to assemble the results of these various investigators in such a way as to compare accurately the actual amounts of the different kinds of nitrogen found by each. In a general way, though, the results agree. Thus the ammoniacal nitrogen seems to represent only a very small part of the total. The amount in the amido form is somewhat greater, while that present as primary amines is the largest of the three. From Schreiner's and Shorey's work some of the remainder consist of pyridine, pyrimidine and purine compounds. Most of the nitrogen in soil organic matter seems, however, to exist in combinations concerning which we know nothing.

Amino Nitrogen in Peat.[1]

It may be seen from this review of the work done on soil organic matter, but little reliable data has been obtained on the amount of amino nitrogen in soils and no general method is in vogue for its determination. As amino nitrogen can usually be easily converted by micro-organisms into a form available for plant use, such a method might be of considerable importance, not only from a scientific standpoint, with a view of determining the constitution of humus compounds, but also from a practical standpoint as an aid in determining the amount of nitrogen available for plant food. While some of the nitrogen of amino acids, and possibly of other amino compounds, may be split off on heating with strong bases, nothing like a complete decomposition could be conveniently obtained, and this method of procedure would also give, as is well known, all of the nitrogen present in the form of ammonia and acid amides. Neither can precipitants of such a general nature as phospho-tungstic acid be depended upon in a mixture of compounds such as one gets in the extract of a soil rich in organic matter. The method originated by Sachsse and Kormann[2] which, as later modified by Boehmer,[3] was used by Dojarenko as previously cited, is free from these objections. Moreover, it has recently been so perfected by Van Slyke[4] that it can be performed with great speed and accuracy. In principle it depends upon the action of nitrous acid on primary amines. In this reaction the nitrogen is set free in the elemental state according to the equation,

$$RNH_2 + HNO_2 \longrightarrow ROH + N_2 + H_2O.$$

and can be measured as such. The NO gas formed by the secondary decomposition of the nitrous acid

$$2\,HNO_2 \longrightarrow NO + NO_2 + H_2O.$$

[1]This part of the work was carried on with the assistance of Mr. O. B. Winter.
[2]Vers. Stat. 17, 88; 17, 321 (1874).
[3]Vers. Stat. 28, 247 (1882).
[4]Proc. Soc. Exp. Biol. and Med. 7, 46 (1910); Beritche d. Deutsh. Chem. Gesel. 43, 3170. (1910.)

is absorbed by potassium permanganate. While the method can apparently be made quite accurate, one factor of uncertainity was met with in the formation, by some secondary reaction, of free nitrogen (?) from the reagents used. The earlier experimenters had this same trouble and Kreusler[1] decided that it was due to the dissociation of NO into elemental nitrogen and oxygen. In running blank determinations, we found that no matter what precautions were used some gas was always left which could not be absorbed in potassium permanganate. This gas was shown by qualitative tests to contain a small amount of oxygen but most of it could not be absorbed in pyrogallic acid. By working under similar conditions this factor may be made practically constant.

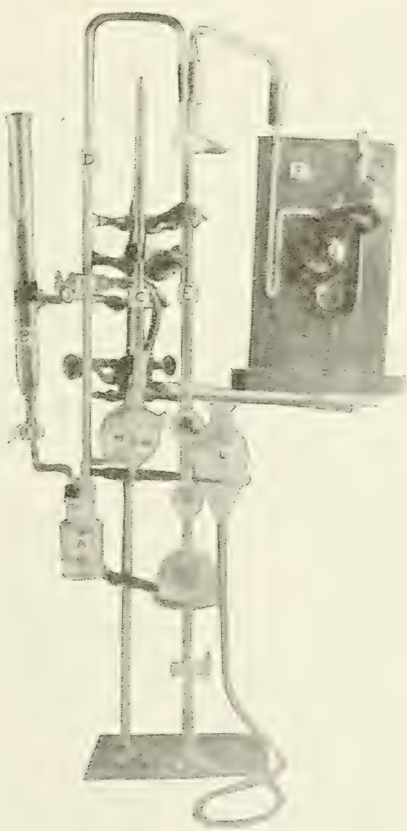

Fig. 1.

The following apparatus (figure I) and method of procedure were used in the determination of amino nitrogen. It is practically the same as was used by Van Slyke. The apparatus consists of a small wide-mouthed bottle (A) of 80 c.c. capacity fitted with a three-hole rubber stopper which supports (1) a glass cylinder (B) closed at the

[1]Vers. Stat. 31, 284 and 302. (1885). See also Sachsse and Kormann, Vers. Stat. 17, 324. (1874)

bottom by a stop-cock, (2) a delivery tube (D) and (3)a 10 c.c. burette (C). The stem of the cylinder which should be of capillary tubing, reaches almost to the bottom of the bottle. The delivery tube is also of capillary tubing of about 1-2 m.m. internal diameter, the upper end being bent twice at right angles to connect with a gas burette (E) while the lower end is flush with the bottom of the rubber stopper. This tube should not extend above the top of the cylinder and should have a three-way Geissler stopcock (K) near the middle. At first an ordinary gas burette was used for measuring the gas volumes and a Hempel pipette (F) for the absorption of the nitric oxide. These two pieces of apparatus were later combined into one piece (E), which served both purposes. It consisted of a 10 c.c. pipette, to one end of which was sealed a series of three bulbs, two of 35 c.c. capacity each and one of about 150 c.c. The ends of this apparatus were closed by stopcocks, a three-way horizontal one at the top and a straight one at the bottom. A leveling bulb (L) was attached to the large bulb and filled with an acid solution of potassium permanganate. In the course of a determination the mixture of gases was collected in this apparatus over the permanganate solution. At the end of the reaction both stopcocks were closed and the gas shaken out in the large bulb, the lower stopcock being opened occasionally to allow the liquid to run in and equalize the pressure. This saves transferring the gas to the Hempel pipette and back to the gas burette and the graduations of the 10 c.c. pipette permit of a more accurate reading than do those of the ordinary gas burette. As an acid permanganate solution liberates gaseous oxygen on standing, several precautions must be taken to guard against error from this source. This piece of apparatus can be used simply as a gas burette in connection with a Hempel pipette as shown in the illustration. In this arrangement one branch of the three-way cock is connected with the delivery tube and the other with the Hempel bulbs which are filled with an alkaline permanganate solution. This solution contains 5 g. $KMNO_4$ and 2.5 KOH per 100 g. H_2O. and has the advantage over the acid solution of being perfectly stable. The gas volumes in this method cannot be read over it directly, however, as the manganese dioxide which is precipitated renders accurate readings difficult. On the whole however the use of the alkaline solution in the Hempel apparatus seems to give the best results.

By introducing the three-way cock instead of the ordinary straight one into the delivery tube it becomes unnecessary to disconnect the gas burette and delivery tube for each determination. This removes one possible source of error in the introduction of air into the apparatus in making this connection. Before starting a determination all air should be driven out of that part of the apparatus between this three-way cock and the Hempel bulbs. This can be accomplished by opening the three-way cock between the gas burette and the Hempel bulbs and lowering the leveling bulb. The permanganate solution will be drawn over filling the connecting tube as far as this cock which can then be turned so as to close this opening and open the one between the gas burette and the delivery tube. By raising the leveling bulb the air can be driven out through this outlet and the burette and delivery tube filled with liquid as far as the cock (K) which should then be turned so as to close the opening towards the gas burette. The cylinder (B) in-

cluding the stem below the stopcock should be filled with water while the 10 c.c. burette should contain the sample which should likewise fill the capillary stem below the stopcock. Both of these together with the delivery tube should be in position in the rubber stopper.

For carrying out the determination, 60 c.c. of a 30 per cent solution of sodium nitrate are placed in the bottle, 15 c.c. of glacial acetic acid added and the bottle wired on to the stopper, the gas escaping through the side outlet of the three-way cock in the delivery tube. The stopcock of the cylinder is next opened, allowing water to run in and completely fill the bottle and that part of the delivery tube below the stopcock, thus displacing all air in the apparatus. The three-way cock in the delivery tube can be completely closed by giving it a slight turn, causing the gas which is being generated in the bottle to force the liquid back into the cylinder. To insure complete removal of air from the apparatus, the bottle and delivery tube are filled a second time with liquid, the excess which escapes through the side arm of the cock (K) being caught in the flask (H). This stopcock is then again closed and 15-20 c.c. of gas allowed to accumulate in the bottle. After closing the outlet to the cylinder, the three-way cock in the delivery tube is turned so as to connect the bottle with the gas burette and the desired amount of sample run in from the 10 c.c. burette. The sample should contain about 5 mg. amino nitrogen per 10 cc. From 5-10 minutes are required for the completion of the reaction, during which time from 80 to 100 c.c. of gas accumulate in the gas burette. After some practice the amount can be so regulated by shaking the bottle that it becomes nearly constant. At the end of the reaction the stopcock of the cylinder is again opened and all the gas in the bottle and delivery tube replaced by liquid. This stopcock is then closed, that in the delivery tube is turned so as to permit the escape, through the side arm, of the gas from the bottle while the three-way cock in the gas burette is completely closed. The gas can be driven into the Hempel apparatus by raising the leveling bulb. After shaking out the nitric oxide with the permanganate solution the nitrogen is run back into the gas burette for measurement.

In preparing solutions for analysis care must be taken that all ammonium compounds are removed and that the solution is not acid with a strong mineral acid. Ammonium compounds react slowly[1] with nitrous acid causing high results while strong mineral acids react too violently with sodium nitrite. Both of these difficulties can be overcome in one operation by adding to a known quantity of the acid solution a slight excess of magnesium oxide and boiling off the free ammonia. The solution can then be filtered and washed from the solid residue and made up to a convenient volume for analysis. The slight alkalinity of the solution after this treatment does not affect the determination.

In calculating the percentage of nitrogen in the sample, it should be remembered that, of the total volume of nitrogen obtained in the gas burette, only one-half comes from the sample, the other half coming from the nitrous acid. This fact adds considerably to the accuracy

[1]Concerning the effect of ammonium compounds in results obtained by this method see the following Kreusler, Vers. Stat. 31, 277: 294. (1885). Emmerling, Vers. Stat. 32, 440. (1886). Van Slyke, Ber. d. Deutsch. Chem. Gesel. 43, 3170. (1910).

of the determination as all errors due to reading the burette, etc. are cut in two in the final result.

The Effect of Acid on the Nitrogenous Compounds of Peat.

Van Slyke[1] has shown that the amount of amino nitrogen formed is a measure of the hydrolysis of protein compounds. He came to this conclusion from the following considerations. From the work of Emil Fischer the combination of amino acids in the protein molecule may be indicated thus,

$$\begin{array}{ccccccccccccc} & & H & & O & & & & H & & O & & \\ H_2N & — & C & — & C & — & N & — & C & — & C & — & OH, \\ & & R & & & & H & & R & & & & \end{array}$$

the group CONH being known as the "peptid group." The nitrogen in this group is in the *imino* (NH) form. Upon hydrolysis, each peptid group takes up a molecule of water forming a free carboxyl (COOH) group and converting the imino (NH) group into an amino (NH_2) group.

$$\begin{array}{ccccccc} & & H & & O & & \\ H_2N & — & C & — & C & — & OH \\ & & R & & & & \end{array} \qquad \begin{array}{ccccccccc} & & & & H & & O & & \\ H & — & N & — & C & — & C & — & OH \\ & & H & & R & & & & \end{array}$$

As the hydrolysis of the compound continues, the proportion of nitrogen in the amino form increases until at complete hydrolysis it reaches a maximum.

Van Slyke has studied the hydrolysis of various protein compounds by different reagents and obtained results which agree with the theory. In each case the rate of formation of amino nitrogen increased rapidly at first but finally approached a constant maximum value. He obtained the following results in the hydrolysis of egg albumen by means of 5 per cent NaOH.

TABLE I.

Hours.	Per cent of total nitrogen.
0	3.00
0.5	7.15
4.5	19.45
25	34.02
48	46.62
96	61.10
144	68.42
Complete hydrolysis	85.20

Upon treating peat with acid a similar change takes place in the amino nitrogen content as is shown by the following table the results of which are shown graphically in Plate I. The peat used in this ex-

[1] Ber. d. Deutsch. Chem. Gesel. 43, 3170; Proc. Soc. Exp. Biol. and Med. 7, 176. (1910).

periment was of the brown variety. After drying at 110° it contained 2.58 per cent nitrogen of which 9.18 per cent was in the form of acid amides. This was determined by heating with sulfuric acid, filtering and distilling with magnesium oxide. In the air-dry state it contained 11.18 per cent moisture and 16.00 per cent ash. It was obtained from the so-called Chandler marsh just north of the city of East Lansing, Michigan. For the following work it was dried at 110° after being pulverized in a mill so that nearly all of it would pass through an 80 mesh sieve. Eight gram samples of this dry material were placed in flasks with 200 c.c. of 25 per cent sulfuric acid and the flasks and contents weighed. The flasks were then fitted with reflux condensers, heated in an oil bath at a temperature of 95° for the desired length of time with frequent shaking and again weighed. Water was added when necessary to bring the weight up to the previous one and the solid residue filtered off with suction. 25 or 50 c.c. samples of this solution were taken and diluted with distilled water. A slight excess of magnesium oxide was added and the ammonia distilled off. The solid residue was then separated from the liquid with suction and thoroughly washed after which the combined filtrate and washings were concentrated and made up to a definite volume of which portions equivalent to 10 c.c. of the original solution were taken for analysis.

For the total soluble nitrogen 10 c.c. samples of the original solution were taken and analyzed by the Kjeldahl method.

TABLE II.

Hours.	Total nitrogen.		Amino nitrogen.	
	c. c. N/10 H_2SO_4.	Per cent of total nitrogen.	c. c. N at 0° and 760 m. m.	Per cent of total nitrogen.
1.00	2.2	29.86	0.76	4.62
3.50	2.7	36.67	1.20	7.30
6.50	3.0	40.74	1.86	11.32
11.75	3.3	44.81	2.18	13.27
18.00	3.4	46.17	2.90	17.65
24.25	3.6	48.89	3.32	20.20
42.50	3.8	51.54	4.12	25.07
90.00	4.5	61.11	4.32	26.17
138.00	4.7	63.83	4.28	26.04

Suzuki[1] concluded from his work that amino acids as such were present only in small quantities in humus. He claimed that they were combined in a complex protein molecule which was broken down by treatment with laboratory reagents with the formation of the free amino acids or their salts. A sample of the brown peat used in the above work was extracted with distilled water for forty-eight hours at 95°. It gave the following figures for amino nitrogen:

10 c. c. of the 200 c. c. used gave 0.27 c. c. N at 760 m. m. =1.64% of the total N

[1]Bul. Coll. of Agric. Tokyo 7, 513. Abs. in Chem. Cent. 1907, Vol. 2, 1650.

All of the above results tend to substantiate Suzuki's conclusion and indicate that at least a part of the nitrogen is present in the form of a complex protein compound which can be hydrolized to form amino acids in much the same way as egg albumen, casein, etc.

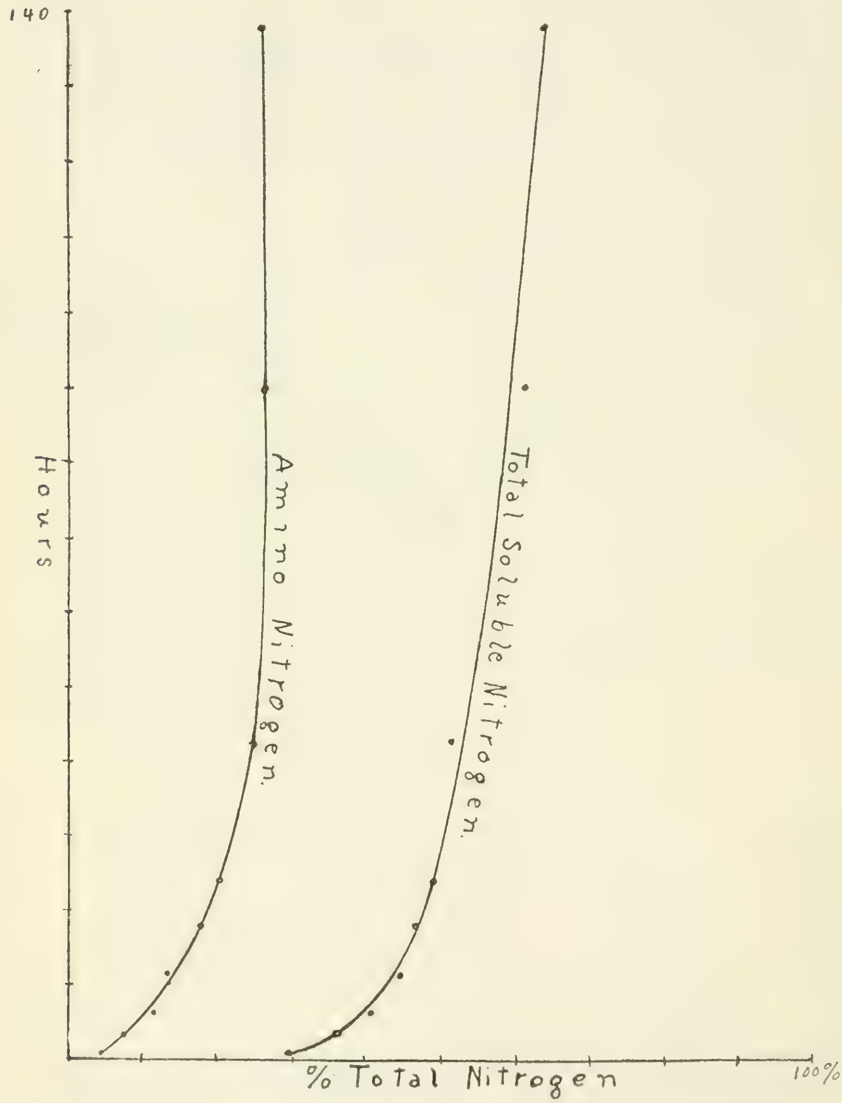

Plate I.

The Isolation of Individual Compounds from Peat.

The brown peat used in the previous experiments was also used in this work. The nitrogenous material was extracted by heating it for

forty-eight hours on the sand bath with 25 parts by weight of 25 per cent sulfuric acid in a flask fitted with a reflux condenser. While still hot, the dark brown liquid was filtered, with suction, through a Buchner funnel having a solid unglazed, porcelain bottom. The insoluble material was returned to the flask, heated with a fresh supply of water and again filtered. This was repeated several times until the wash water came through colorless. The filtrate and washings were made alkaline with slaked lime and the precipitate of calcium sulfate allowed to settle. The supernatant liquid was then poured through a filter and the precipitate washed several times by decantation with hot water. The liquid thus obtained was concentrated to about one-third its volume and filtered from a small precipitate of calcium sulfate and humus. Barium hydroxide was added to the filtrate in slight excess and the precipitate of barium sulfate filtered off and thoroughly washed.[1] The hydroxides of barium and calcium remaining in solution were then removed by passing carbon dioxide into the hot solution and filtering off the precipitated carbonates by suction. By this process all of the sulfuric acid can be removed together with the reagents used for its removal, leaving only the products of the extraction in solution. Most of the brown, amorphous, humus material is held back so that at the end one has, at most, only a light brown solution. The amount of mineral matter was very small and was precipitated as a light-colored, sandy powder, during the concentration, before the organic matter came down. After removing this small precipitate, the solution was made slightly acid and a solution of phosphotungstic acid slowly added until it failed to cause a further precipitation. The precipitate thus formed was light gray and flocculent. It was filtered off and washed with hot water. Both the filtrate and precipitate were then boiled with an excess of barium hydroxide and filtered, after which the excess of barium hydroxide was removed with carbon dioxide and the solutions concentrated. The one resulting from the decomposition of the phosphotungstic acid yielded only a brown viscous mass, which failed to crystallize.

A light yellow scale formed on the surface of the other solution and as the concentration was continued, waxy knobs and clusters were formed on the sides of the dish. This material was separated from the rather oily mother liquor, dissolved in water and, after boiling with animal charcoal, recrystallized. After several recrystallizations it was obtained colorless, separating in waxy knobs and clusters when allowed to crystallize slowly or as a white crust when the mother liquor was more concentrated. It was further purified by precipitation from a concentrated aqueous solution with absolute alcohol. After being purified in this way it crystallized in white flakes. It was readily soluble in water but almost insoluble in absolute alcohol and most organic solvents. The aqueous solution was neutral to litmus. When the solid substance was heated in a capillary tube it softened at 230° and decomposed at 265-269°, giving a white crystalline sublimate in the upper part of the tube. The mother substance analyzed as follows:

0.0696 g. subst. gave 6.7 cc. N at 25° and 748 mm.
Calculated for $C_6H_{13}O_2N$: N, 10.68. Found, 10.56 per cent.

[1]Where only small quantities of peat and sulfuric acid are used, it is, of course, better to precipitate all of the acid with barium hydroxide. When large quantities of acid are being used, however, it is more economical to precipitate the bulk of it with lime and use the barium only for that which remains in solution as calcium sulfate.

Copper Salt.—Several hundred milligrams were dissolved in boiling water and the solution saturated with copper carbonate. Carbon dioxide was evolved and the solution turned dark blue. A light blue scum formed on the surface. The solution was filtered hot and concentrated, upon which a dark blue crystalline copper compound separated out. It gave 19.63 per cent copper; calculated for $(C^6H^{12}NO^2)_2Cu$, 19.64 per cent.

These figures indicated that it might be one of the aminocaproic acids of which leucine is the most prominent. The light blue scum which had been filtered off was dissolved in water, in which it was difficultly soluble. From this it was evident that the original material contained two compounds, one forming a copper salt easily soluble in water, the other forming a copper salt difficultly soluble in this solvent. As was shown by Ehrlich, such is the case with leucine and isoleucine. His method for separating these two substances was based on the fact that the isoleucine copper salt is readily soluble in cold concentrated methyl alcohol while the corresponding leucine compound is practically insoluble. Unfortunately this ideal condition of affairs does not hold absolutely when both substances are present. In a mixture of these compounds some of the leucine copper salt dissolves in the alcoholic solution of the isoleucine salt while some of the latter is held back in the crystals of the former. For complete purification of the leucine, Ehrlich[1] suggested that, after extracting as thoroughly as possible, the leucine copper salt be decomposed with hydrogen sulfide, the copper sulfide be filtered off and the copper salt again formed and extracted as before. Several repetitions of this procedure should remove all of the isoleucine. Recrystallization from water removes the leucine completely from the isoleucine.

Leucine.—The solution of the mixed copper salts as originally obtained was taken to dryness on the steam bath. The resulting light blue, crystalline mass was extracted with small portions of cold concentrated methyl alcohol until the solvent was no longer colored after having been shaken some time with the salt. The solid residue was then dissolved in water and decomposed with hydrogen sulfide. After filtering off the copper sulfide the solution was saturated with copper carbonate, the excess filtered off and the solution taken to dryness as before. This copper salt was again extracted with methyl alcohol and the process repeated twice. The last extraction removed only a trace of copper from the solid residue. This was then dissolved in water, and decomposed with hydrogen sulfide. The copper sulfide was filtered off and the solution concentrated. It was levorotatory. The white crystalline substance which separated out gave the following rotation in 20 per cent hydrochloric acid.

0.0455 gram substance in 11.1373 gram solution (0.4085 per cent; 1.086 sp. gr.) gave $+0.40°$ (Ventzke) rot. in a 2 dm. tube at 20°, sodium light.

$$[a]_D^{20} \text{ found} = +\ 15.62.$$

$$[a]_D^{20}\ l\text{-leucene} = +\ 17.3.$$

When heated quickly in a capillary tube it melted at 287°. The copper salt gave the following figures for nitrogen and copper:

[1]Ber., 37, 1809 (1904).

0.0585 gram substance gave 5.0 cc. moist nitrogen (28°, 738 mm).
0.0291 gram substance gave 0.0072 gram CuO.

Calculated for $(C_6H_{12}O_2N)_2Cu$: N, 8.65; Cu, 19.64. Found: N, 9.10; Cu, 19.76 per cent.

Isoleucine.— The combined methyl alcohol extracts from the leucine were concentrated. After drying at 110°, the dark blue copper compound analyzed as follows: 0.0539 gram substance gave 0.0133 gram CuO.

Calculated for $(C_6H_{12}O_2N)_2Cu$: Cu, 19.64. Found, 19.72 per cent.

After recrystallizing once from water, the copper was precipitated by hydrogen sulfide and the solution concentrated. The pure, white crystalline compound was filtered from the mother liquor, washed with alcohol and ether and dried at 110°. It melted at 272° when heated quickly. It had the following specific rotation:

In water, 0.3227 gram substance in 14.6053 grams solution (2.21 per cent; 1.0053 sp. gr.) gave +1.1° (Ventzke) rotation in a 2 dm. tube at 20°, sodium light.

$$[a]_D^{20} \quad \text{found} = +8.58.$$

$$[a]_D^{20} \text{ for isoleucine} = +9.74.$$

In 20 per cent hydrochloric acid, 0.1965 gram substance in 13.4543 grams solution (1.46 per cent; 1.0871 sp. gr.) gave +3.25° (Ventzke) rotation in a 2 dcm. tube at 20°, sodium light.

$$[a]_D^{20} \quad \text{found} = +\ 35.47.$$

$$[a]_D^{20} \quad \text{isoleucine} = +\ 36.80.$$

It analyzed as follows for nitrogen:

Calculated for $C_6H_{13}O_2N$: N, 10.68. Found: N, 10.89 per cent.

From these results there can be no doubt as to the identity of the two compounds in question. Both of them are well known decomposition products of protein and one of them, leucine, was among the compounds isolated by Suzuki from humic acid.

Experiments with other Samples of Peat.

As has been mentioned before,[1] Jodidi determined the amounts of mono— and diamino nitrogen in acid extracts of peat using phosphotungstic acid for precipitating the diamino acids. His conclusions were based on the assumption that all acid-soluble nitrogen is in the form of ammonium compounds, acid amides, mono— or diamino acids. That this assumption is unwarranted seems probable from the fact that many of the common constituents of plants, from which peat is formed, are compounds in which some of the nitrogen is not in any one of these four forms. To test this point analyses were made by Van Slyke's method of samples of two of the peats used by Jodidi.[2] In the

[1]P. 11.
[2]The conditions of extraction approximated as closely as possible those of Experiments 7 and 12, Journ. Am. Chem. Soc. 32, 402; Tech. Bull. 4, Mich. Exp. Sta., Table I, p. 14.

extractions the ratios of acid to peat were slightly higher than in Jodidi's work as we used 13.5 g. of oven-dried peat to 630 and 330 g. of acid making ratios of 45.6 and 24.4 for the brown and black peats respectively as compared with 41 and 21 in his work. If anything, this should increase the amounts of amino nitrogen in our results. At the time this work was done the samples of peat analyzed for total nitrogen as follows:

Brown	2.59 per cent.
Black	1.85 per cent.

BROWN PEAT.

15 g. sample gave 3.23 cc. N at 760 mm. and 0°=24.96 per cent of the total.
Found by Jodidi 41.19 per cent of the total.

BLACK PEAT.

15 g. sample gave 4.52 cc. N at 760 mm. and 0°=25.97 per cent of the total.
Found by Jodidi 43.02 per cent of the total.

As was anticipated these results were lower than his. They agree well with the results on the brown peat previously described which would indicate that the amino nitrogen content of peat is a fairly constant quantity.

A sample of this black peat was extracted with 25 per cent sulfuric acid and the extract treated as described on page 18. Upon concentrating the sulfate-free liquid the characteristic yellow scale formed. It was separated from the mother liquor and purified as in the previous case. The quantity was too small to permit of a separation of the isomers. The material was converted into the copper salt which analyzed as follows:

0.0720 gram substance gave 0.1169 gram CO_2 and 0.0485 gram H_2O.
0.0302 gram substance gave 0.0075 gram CuO.
Calculated for $(C_6H_{12}NO_2)_2Cu$: C, 44.48; H, 7.47; Cu, 19.64. Found: C, 44.29; H, 7.53; Cu, 19.85.

The substance was evidently a mixture of the two compounds described above.

SUMMARY.

It is evident from the work done up to the present time on the nitrogenous material of soil organic matter that the subject is an exceedingly complex one. Evidently the decomposition products of plants contain compounds of great structural variety. The work reported in this paper and that done by Suzuki proves quite conclusively that a considerable portion of the nitrogen is present in the form of a protein compound or a mixture of such compounds which can be broken down on treatment with acids in the same manner as casein, egg albumen, etc. In the samples of peat studied for this work about 26 per cent of the total nitrogen was combined in this form in such a way that it could be converted by hydrolysis into primary amines, probably with

the formation of amino acids. About ten per cent of the total nitrogen is due to the presence of acid amides. From the work of Schreiner and Shorey purine, pyrimidine and pyridine compounds constitute a part of the remainder. The greater part is, however, present in forms concerning which we know nothing and which may represent the most important factors in aiding or inhibiting plant growth. It seems probable, from the work done so far, that the classes of compounds constituting this unknown residue are many. If this is true the possibility of ever getting a simple laboratory method for determining the so-called availability of organic nitrogenous material seems hopeless, as the difference in the action of soil agents upon different substances is undoubtedly very marked. The factor of toxicity must also be taken into consideration. Even though some method might be devised for imitating the action of soil agents in breaking down soil organic matter the presence of substances poisonous to plant growth is always a possibility until sufficient knowledge has been obtained of the kinds and amounts of the various compounds present for us to make positive statements to the contrary. The greatest need at present in determining the value of the organic nitrogenous material of peat and humus is a closer knowledge of the individual substances actually present in such material and those which may possibly be formed by natural agents in the soil. Until this knowledge shall have been gained all attempts at the utilization of this material must be made more or less blindly and by empirical and uncertain methods.

In conclusion the author wishes to express his thanks to Dr. D. D. VanSlyke of the Rockefeller Institute for Medical Research for his kindly interest and helpful suggestions regarding this work.

FOREWORD.

Technical Bulletin No. 8.

BY WARD GILTNER.

The present bulletin continues the work published in Technical Bulletin No. 3 of this station, giving, however, more extensively and definitely the agglutinative relation of the blood-serum secured from normal, virus, immunized, and hyperimmunized pigs to *B. cholerae suis*. While the work established the fact that no dependence may be placed upon the degree of agglutination to indicate the potency of serum, it has been the means of providing many interesting and useful data as well as suggestions. These suggestions will be the basis of further investigations.

It becomes more and more apparent that, *notwithstanding the value and utility of the Dorset-Niles serum as it is now manufactured,* the problems concerning the practical manufacture and application call for renewed effort. A more intimate knowledge of the processes involved becomes essential to the most intelligent production and use. A solution can be found only in a study of the filterable virus, B. cholerae suis, and the organism of the pig as they are associated in this disease, hog cholera.

CHARLES E. MARSHALL.

STUDIES OF AGGLUTINATION REACTIONS IN HOG CHOLERA DURING THE PROCESS OF SERUM PRODUCTION.

(*Continued.*)

I. INTRODUCTION.

PURPOSE.

The purpose of this paper is to set forth the results of experiments made in an effort to complete the work previously published.[1] We are able to present a greater amount of data covering some of the points already considered and, in addition, a more or less comprehensive account of many features not previously considered.

A scientific understanding of swine epizoötics, covering such points as their etiology, serum therapy, and control, demands an answer to the preplexing question of the relation of *B. cholerae suis* (*B. suipestifer*) and *Bact. septicaemiae hemorrhagicae* (*Bact. suisepticum*) to these diseases. We have concerned ourselves only with the former of these organisms, the latter not having been isolated by us. As a result of our preliminary work, we were encouraged in the belief that a study of agglutination reactions in all the various stages of serum production might furnish a positive solution for some of the unsettled problems. We also hoped that there might be some definite relation between the agglutinative power of a serum toward B. cholerae suis and its immunizing power in vivo. In other words, we hoped to standardize the serum by the agglutination test.

PREVIOUS RESULTS.

Our work, in accord with that of many others, shows the pathogenicity of pure cultures of *B. cholerae suis* for swine under certain conditions. As a result of a limited number of observations, we have concluded that, "Pigs immunized according to the Turner-Kolle method may withstand intravenous injections of virulent cultures of *B. cholerae suis*." We are not aware of any one having demonstrated an outbreak of hog cholera due to *B. cholera suis* only,* excluding the possibility of the presence of the filterable virus as an etiological factor. A careful study of the literature added to our experience with hog cholera in connection with the production and application of Dorset-Niles serum leaves us undecided as to the necessity of opposing an artificial immunity against an organism regarded by many, as Hottinger[2] puts it, as a colon-like organism invading the blood from its habitat, the intestinal canal, and possessing only acquired pathogenic properties. What

* The work of Dammann and Stedefeder (Rep. 4) may furnish a possible exception to this statement

the significance of "acquired pathogenic properties" may be, and what their acquisition may mean to a herd of hogs does not appear in the literature.

It seems to us good policy to persistently attempt to establish the fundamental points bearing upon the etiology of swine epizoötics, and, at the same time, vigorously but cautiously, to avail ourselves of all effective means of controlling these outbreaks even in the absence of a comprehensive understanding of the modus operandi of the means employed.

PLAN OF WORK.

The agglutination work has been conducted, as before, in connection with routine serum production, and on account of the great expense of this kind of animal experimentation, the plan has been to interfere as little as possible with the routine serum work. We have been able to follow the changes in the agglutinative power of the blood of a number of animals through various stages of treatment. The tabulated results show the differences in agglutinative power of the blood of normal pigs, of pigs treated with hog cholera virus alone or simultaneously with the protective serum, and of pigs treated with increasing doses of virus during the hyper-immunizing process. The results of efforts to measure the potency of serum by the agglutination reaction are shown under the tables covering the testing of mixed sera and table XXV.

TECHNIC.

The methods employed are essentially the same as in the previous work except that bouillon cultures of *B. cholerae suis* are used instead of a carbol-salt-solution suspension of agar slant cultures killed by heat. Flasks containing 50 cc. of ordinary bouillon are inoculated just before leaving the laboratory in the afternoon, and placed at 37°C. Upon returning to the laboratory 16 hours later, it is found that the cultures are uniformly turbid. A limited number of counts indicates the presence of from one-half to one billion organisms per cc. The cultures are too cloudy for the agglutination test, and are diluted by the addition of an equal volume of 0.85 per cent Nacl solution containing 0.4 per cent formalin. This puts the organisms in a 0.2 per cent formalin solution. The flasks are then kept in a cool room, and agitated daily. Sub-cultures usually show no growth after the second day.

The bacterial suspension prepared in this manner gives satisfactory results after 24 days at least, and probably can be used after a much longer time. Hiss,[3] working with dead typhoid cultures prepared in a similar way, states that there is "no change in their limit of agglutination even after weeks." The advantages in this method are the facility with which a large volume of bacterial emulsion is secured and the uniformity of the successive preparations.

It is essential in comparative agglutination tests that the number of organisms in the bacterial suspensions be fairly constant. The use of a nephelometer for standardizing the density of the emulsion does not appeal to us so strongly as uniform methods of producing the emulsion.

It has seemed desirable to determine in each case the limit of the agglutinative power of each serum tested. In order to do this, we have attempted to test the serum at dilutions both above and below the limit and at the same time to employ only five different dilutions. This is possible only when we can make a close estimate as to the probable maximums at which agglutination will occur. Previous tests with blood serum from the same animal and a knowledge of the treatment to which the animal has been subjected are the only indications. The agglutinative power of a serum, as measured by the system of dilutions, does not always diminish at a ratio capable of being computed from the data furnished by the observation of a considerable number of dilutions. To make this point clear, it is only necessary to study a table of reactions when it will be found that a complete reaction at one dilution is followed in some cases by a gradual diminution of the strength of the reaction through several succeeding dilutions while in other cases a complete reaction may be followed in unvarying intensity throughout a considerable number of dilutions. This discussion is of more general interest, however, than the subject of this paper will permit. Still, we are convinced that our understanding of the nature of the agglutination reaction and the technic involved in making the test is very crude.

CULTURES USED.

Two cultures from different sources, but probably the same strain, were used in all the tests recorded here. Comparative tests demonstrated that there was no appreciable difference in the agglutinability of these two cultures of *B. cholerae suis*. Indeed they must have had a common source unless the *B. cholerae suis* found in the blood and other tissues of "virus pigs" finds its way there from its alleged normal habitat, the intestines, of each pig treated.

Culture "virus 122" came from the spleen of virus pig 122.

Virus pig 122, wt. 75 lbs., was inoculated in the muscles of the ham 9-23-09 with 5 cc. virus blood from Expt. pig 216. The pig was killed 9 days after inoculation after showing characteristic symptoms of hog cholera.

Autopsy: Inguinal glands quite hemorrhagic; iliac glands enlarged and hemorrhagic; renal glands hemorrhagic; kidneys show few petechiae in both cortex and medulla; spleen enlarged and friable.

Culture "virus 136" came from the spleen of virus pig 136.

Virus pig 136, wt. 81 lbs., was inoculated in the muscles of the ham 11-30-09 with 5 cc. of virus blood from virus pig 128. Was killed 11 days later after showing symptoms of hog cholera.

Autopsy: Cortex of inguinal and iliac glands hemorrhagic; kidneys show petechiae in both cortex and medulla; spleen enlarged, dark and friable; liver shows slight superficial necrosis; intestinal mucosa sprinkled with numerous petechiae; lungs, hemorrhagic.

These cultures were plated on agar and typical colonies were seeded on the various media necessary for the identification of *B. cholerae suis*. Infectiousness for rabbits was also determined. Pathogenicity for pigs was not determined except that large quantities of culture "virus 136" were injected intramuscularly into an immune pig (Expt. 315) with the result that only local abscesses were produced.*

*The object and results of this work will be recorded later.

Since these cultures respond similarly when tested with the same sample of serum, it is of interest to trace their origin.

The original "Ames virus" which is the basis of all our routine work, was kept in sealed bulbs for over six months. The successive transfers were then as follows:

"Ames virus" to Expt. pig 124, to Expt. pig 199, to Expt. pig 216, to virus 122.

"Ames virus" to Expt. pig 123, to Expt. pig 197, to virus 124, to virus 128, to virus 136.

"In studying the reaction,—we take into consideration two factors, viz.—(a) The clumping or agglutination of the bacteria and consequent clearing of the test fluid and (b) The formation of a characteristic membrane on the bottom of the tube." In the tables under each dilution are the signs (+ — o) arranged in two columns to indicate the degree of reaction having reference to the two factors considered above.

TABLE I.—*Agglutination Tests With Normal Serum and Culture "Virus 122."*

In the table, the sign (+) indicates a complete reaction, the sign (—) indicates that the reaction has progressed considerably, but not completely, and the sign (0) indicates no change.

Dilution of serum.			25.		50.		100.		125.		250.		500.	
No. of pig.	Weight.	Date tested.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
Expt. 293...	36 lbs.	11-24-09	......	......	0	0	0	0	0	0	0	0	0	0
Expt. 294...	33 lbs.	11-24-09	......	......	—	—	0	0	0	0	0	0	0	0
Expt. 295...	33 lbs.	11-24-09	......	......	0	0	0	0	0	0	0	0	0	0
Expt. 296...	27 lbs.	11-24-09	......	......	0	0	0	0	0	0	0	0	0	0
Expt. 297...	26 lbs.	11-24-09	......	......	0	0	0	0	0	0	0	0	0	0
Expt. 298...	26 lbs.	11-24-09	......	......	0	0	0	0	0	0	0	0	0	0
Expt. 299...	35 lbs.	11-24-09	......	......	—	—	0	0	0	0	0	0	0	0
Expt. 300...	42 lbs.	11-24-09	......	......	0	0	0	0	0	0	0	0	0	0
Expt. 301...	35 lbs.	11-24-09	....	......	0	0	0	0	0	0	0	0	0	0
Expt. 302...	32 lbs.	11-24-09	......	......	0	0	0	0	0	0	0	0	0	0
Expt. 303...	28 lbs.	11-24-09	......	......	0	0	0	0	0	0	0	0	0	0
Expt. 304...	30 lbs.	11-24-09	......	......	0	0	0	0	0	0	0	0	0	0
Expt. 305...	49 lbs.	12- 2-09	—	—	0	0	0	0	0	0	0	0	0	0
Expt. 306...	49 lbs.	12- 2-09	—	—	—	—	—	—	—	—	—	—	......	......
Expt. 307...	48 lbs.	12- 2-09	—	—	0	0	0	0	0	0	0	0	......	......
Expt. 308...	44 lbs.	12- 2-09	—	—	0	0	0	0	0	0	0	0	....	......
Expt. 309...	44 lbs.	12- 2-09	0	0	0	0	0	0	0	0	0	0	......	......
Expt. 310...	36 lbs.	12- 2-09	0	0	0	0	0	0	0	0	0	0	......	......
Expt. 311...	55 lbs.	12- 2-09	+	+	—	—	—	—	—	—	—	—	......	......
Expt. 312...	44 lbs.	12- 2-09	—	—	0	0	0	0	0	0	0	0	......	......
Expt. 313...	46 lbs.	12- 2-09	—	—	—	—	—	—	—	—	0	0	......	......
Expt. 314...	50 lbs.	12- 2-09	—	—	0	0	0	0	0	0	0	0	......	......
Expt. 315...	37 lbs.	12- 2-09	0	0	0	0	0	0	0	0	0	0	......	......
Expt. 316...	27 lbs.	12- 2-09	0	0	0	0	0	0	0	0	0	0	......	......
Expt. 317...	50 lbs.	12-18-09	—	—	0	0	0	0	0	0	0	0	......	......
Expt. 318...	51 lbs.	12-18-09	—	—	—	—	—	—	—	—	0	0	......	......
Expt. 319...	49 lbs.	12-18-09	0	0	0	0	0	0	0	0	0	0	......	......
Expt. 320...	44 lbs.	12-18-09	0	0	0	0	0	0	0	0	0	0	......	......
Expt. 321...	42 lbs.	12-18-09	—	—	—	—	0	0	0	0	0	0	......	......
Expt. 322...	53 lbs.	12-18-09	—	—	—	—	—	—	—	—	0	0	......	......
Virus 138....	96 lbs.	12-11-09	......	......	+	—	—	—	—	—	0	0	0	0
Virus 138....	83 lbs.	12-11-09	......	......	+	—	—	—	—	—	0	0	0	0

REACTIONS WITH NORMAL SERA.

We have already recorded the reactions with the blood of 9 normal pigs. Of these, 3 gave a reaction at 1-125, the remaining 6 gave only a slight reaction at 1-50. In Table I are recorded the reactions with the blood of 32 normal* pigs. Of the 32 samples of normal blood tested,

6 or 18.75	per cent gave no reaction at a dilution of 1—25.
6 or 18.75	per cent gave a reaction at a dilution of 1—25.
10 or 31.25	per cent gave no reaction at a dilution of 1—50.
3 or 9.375	per cent gave a reaction at a dilution of 1—50.
5 or 15.625	per cent gave a reaction at a dilution of 1—125.
2 or 6.25	per cent gave a reaction at a dilution of 1—250.

In the second column of Table I are given the weights of the pigs at the time the sample of blood was drawn. It was found that, in the former records, of the three normal pigs whose blood gave a reaction at 1-125 that the average weight was 66 lbs., and of the six normal pigs whose blood gave a reaction at 1-50 the average weight was 23 lbs. We find from a study of Table I that of the

6 pigs giving no reaction at 1—25	the average weight is 39 lbs.
6 pigs giving a reaction at 1—25	the average weight is 47 lbs.
10 pigs giving no reaction at 1—50	the average weight is 31 lbs.
3 pigs giving a reaction at 1—50	the average weight is 37 lbs.
5 pigs giving a reaction at 1—125	the average weight is 63 lbs.
2 pigs giving a reaction at 1—250	the average weight is 52 lbs.

We see in these results a tendency for the agglutinative power of the serum to increase with the size or more probably the age of the pig. This point cannot be considered determined by the few tests recorded here. The results, however, are suggestive.

REACTIONS WITH THE BLOOD OF PIGS TREATED WITH VIRUS.

Table II shows the agglutination reactions with the blood of 56 pigs inoculated with virus of hog cholera, i. e., with blood drawn from a pig showing symptoms and lesions of hog cholera. There is also shown a considerable amount of other data included with the hope that the interpretation of the agglutination reactions may be facilitated.

*The word "normal" is used in the sense that the pig has neither been exposed to hog cholera nor subjected to any treatment.

TABLE II.—*Agglutination tests with the blood of pigs inoculated with virus.*

In the table, the sign (+) indicates a complete reaction, the (—) indicates that the reaction has progressed considerably, but not completely, and the sign (o) indicates no change.

Dilution of serum.							50.		100.		125.		250.		500.		800.	
Number of pig.	Weight, lbs.	Date sample drawn.	Amount of virus injected into pig.	Days lived after injection.	Died.	Killed.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
Virus 121	75	10-2 09	5 cc. expt. 216	9	......	yes	......	......	......	......	......	......	......	......	—	—	0	0
Virus 122	75	10-2 09	5 cc. expt. 216	9	......	yes	......	......	......	......	......	......	......	......	—	—	0	0
Virus 124	75	10-5 09	5 cc. expt. 197	10	......	yes	......	......	......	......	......	......	......	......	—	—	—	—
Virus 127	65	11-20 09	5 cc. virus 124	9	......	yes	—	—	0	0	0	0	0	0	0	0	......	......
Virus 128	63	11 20 09	5 cc. virus 124	9	......	yes	0	0	0	0	0	0	0	0	0	0	......	......
Virus 129	63	11 21 09	5 cc. virus 122	6	......	yes	+	—	+	—	+	—	+	—	—	—	......	......
Virus 130	52	11-22-09	5 cc. virus 122	7	......	yes	+	—	—	—	—	—	—	—	0	0	......	......
Virus 131	83	11 24 09	5 cc. virus 124	6	......	yes	+	+	—	—	—	—	0	0	0	0	......	......
Virus 132	91	11 26 09	5 cc. virus 124	7	......	yes	—	—	—	—	0	0	0	0	0	0	......	......
Virus 137	75	12- 9-09	5 cc. virus 127	9	......	yes	+	+	+	+	+	+	+	—	—	—	......	......
Virus 138	96	12 15 09	5 cc. expt. 199	8	......	yes	+	+	+	—	+	—	+	—	—	—	......	......
Virus 140	84	12 22-09	5 cc. virus 136	8	......	yes	......	......	......	......	......	......	—	—	0	0	......	......
Virus 141	98	12 23-09	5 cc. virus 136	9	......	yes	......	......	......	......	......	......	—	—	—	—	......	......
Virus 143	83	1- 7-10	5 cc. virus 124	8	......	yes	+	+	+	—	+	—	+	—	—	—	......	......
Virus 145	52	1 12 10	5 cc. virus 128	6	yes	......	......	......	......	......	......	......	+	—	0	0	0	0
Virus 146	51	1 12 10	5 cc. virus 128	6	......	yes	......	......	......	......	......	......	—	—	0	0	0	0
Virus 151	54	2- 3-10	5 cc. virus 125	9	......	yes	—	—	0	0	0	0	......	......	......	......	......	......
Virus 152	54	2- 3-10	5 cc. virus 127	9	yes	......	—	—	—	—	0	0	0	0	0	0	0	......
Virus 153	37	2- 3-10	5 cc. virus 127	9	yes	......	—	—	—	—	—	—	0	0	0	0	......	......
Virus 156	63	2- 9-10	5 cc. virus 107	7	......	yes	+	—	—	—	—	—	—	—	—	—	......	......
Virus 157	57	3-26-10	5 cc. virus 125	26	lived.	......	+	—	—	—	—	—	—	—	—	—	......	......
Virus 160	51	3-15-10	5 cc. virus 125	10	......	yes	—	—	—	—	—	—	—	—	0	0	......	......
Virus 161	43	3 17 10	5 cc. virus 125	9	......	yes	—	—	0	0	0	0	0	0	0	0	......	......
Virus 162	43	3 17 10	5 cc. virus 125	9	......	yes	0	0	0	0	0	0	0	0	0	0	......	......
Virus 165	55	3 25 10	8 cc. virus 121	8	......	yes	+	+	+	+	+	+	+	+	—	—	......	......
Virus 166	53	3 25-10	8 cc. virus 121	8	......	yes	—	—	—	—	—	—	—	—	—	—	......	......
Virus 167	61	4 16 10	10 cc. virus 106	8	......	yes	+	+	+	—	+	—	—	—	—	—	......	......
Virus 168	58	4 16 10	8 cc. expt. 199	8	......	yes	+	+	+	—	—	—	—	—	—	—	......	......
Virus 169	62	4 16 10	9 cc. expt. 268	8	......	yes	+	+	+	+	+	+	+	—	—	—	......	......
Virus 170	68	4 16 10	8 cc. expt. 197	8	yes	......	+	+	+	+	+	+	+	+	+	—	......	......

TABLE II.—*Concluded.*

Dilution of serum.							50.		100.		125.		250.		500.		800.	
Number of pig.	Weight, lbs.	Date sample drawn.	Amount of virus injected into pig.	Days lived after injection.	Died.	Killed.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
Virus 171	60	4-16-10	9 cc. expt. 200	8	yes	......	+	—	—	—	—	—	—	—	—	—	......	......
Virus 172	59	4-23-10	10 cc. virus 170	7	......	yes	—	—	—	—	—	—	—	—	0	0	......	......
Virus 173	59	4-23-10	10 cc. virus 169	7	......	yes	—	—	—	—	—	—	—	—	0	0	......	......
Virus 174	50	4-22-10	10 cc. virus 167	6	......	yes	—	—	—	—	—	—	—	—	0	0	......	......
Virus 176	57	4-22-10	10 cc. virus 171	6	......	yes	+	—	—	—	—	—	—	—	0	0	......	......
Virus 178	65	5- 7-10	10 cc. virus 171	5	......	yes	+	+	+	+	+	—	—	—	—	—	......	......
Virus 181	78	5-13-10	10 cc. expt. 398	8	......	yes	+	—	+	—	—	—	—	—	—	—	......	......
Virus 183	124	5-21-10	10 cc. virus 179	5	......	yes	+	+	+	+	+	+	+	+	—	—	—	—
Virus 184	86	5-21-10	10 cc. virus 179	5	......	yes	+	+	+	+	+	+	+	+	—	—	—	—
Virus 185	92	5-26-10	10 cc. virus 182	7	......	yes	+	+	—	—	—	—	—	—	—	—	......	......
Virus 186	75	5-26-10	10 cc. virus 182	7	......	yes	—	—	—	—	—	—	—	—	0	0	......	......
Virus 187	138	6-16-10	10 cc. virus 125	7	......	yes	+	—	—	—	—	—	0	0	0	0	......	......
Virus 188	125	6-16-10	5 cc. virus 175	7	......	yes	—	—	—	—	0	0	0	0	0	0	......	......
Virus 189	106	6-21-10	10 cc. virus 170	7	......	yes	+	—	—	—	—	—	0	0	0	0	......	......
Virus 190	111	6-21-10	8 cc. virus 175	7	......	......	+	—	—	—	—	—	0	0	0	0	......	......
Virus 191	89	6-21-10	8 cc. expt. 425	7	......	yes	—	—	0	0	0	0	0	0	0	0	......	......
Expt. 291	24	12- 9-09	5 cc. from Canada	38	yes	......	—	—	—	—	—	—	—	—	0	0	......	......
Expt. 298	25	12-26-09	1 cc. virus 124	8	......	yes	—	—	—	—	—	—	0	0	0	0	......	......
Expt. 310	36	12-11-09	1 cc. virus 127	12	yes	......	+	+	+	+	—	—	—	—	—	—	......	......
Expt. 316	27	12-11-09	1 cc. virus 128	11	......	yes	+	+	+	—	+	—	—	—	—	—	......	......
Expt. 319	49	1-18-10	2 cc. virus 131 filtered	35	yes	......	0	0	0	0	0	0	0	0	0	0	......	......
Expt. 377	13	1-31-10	1 cc. virus 129	6	yes	......	0	0	0	0	0	0	0	0	0	0	......	......
Expt. 334	45	1-25-10	1 cc. virus 124	18	yes	......	0	0	0	0	0	0	0	0	0	0	......	......
Expt. 394	44	3-27-10	1 cc. virus 158—2 cc. 164	15	yes	......	—	—	—	—	—	—	—	—	0	0	......	......
Expt. 409	24	5- 5-10	2 cc. virus 170	7	yes	......	0	0	0	0	0	0	0	0	0	0	......	......
Expt. 419	23	6- 2-10	1 cc. virus 175	8	......	yes	0	0	0	0	0	0	0	0	0	0	......	......

Of the 56 samples of virus blood tested,

7 or 12.5 per cent gave no reaction at a dilution of 1—50.
4 or 7 1-7 per cent gave a reaction at a dilution of 1—50.
3 or 5 5-14 per cent gave a reaction at a dilution of 1—100.
6 or 10 5-7 per cent gave a reaction at a dilution of 1—125.
12 or 21 3-7 per cent gave a reaction at a dilution of 1—250.
21 or 37.5 per cent gave a reaction at a dilution of 1—500.
3 or 5 5-14 per cent gave a reaction at a dilution of 1—800.

It is readily apparent that the blood of pigs treated with hog cholera virus acquires agglutinin for B. cholerae suis considerably in excess of that found in normal serum. For, whereas only 6¼ per cent of the samples of normal serum agglutinated at a dilution of 1-250, 64 2-7 per cent of the samples of virus blood agglutinated at a dilution of 1-250 or above.

In studying the influence of body weight* upon the agglutinin content of the blood of hog cholera pigs, we get results similar to those recorded under normal serum.

The average weight of

7 pigs whose blood did not react at 1—50 is 37 lbs.
4 pigs whose blood reacted at 1—50 is 63 lbs.
3 pigs whose blood reacted at 1—100 is 90 lbs.
6 pigs whose blood reacted at 1—125 is 83 lbs.
12 pigs whose blood reacted at 1—250 is 55 lbs.
21 pigs whose blood reacted at 1—500 is 66 lbs.
3 pigs whose blood reacted at 1—800 is 95 lbs.

It must be admitted that the relation between weight and agglutinative power of serum is only suggested by these figures. We do not wish to make any generalization yet.

The next factor to be considered that may influence the agglutinative power of the virus blood is the treatment, in other words, the amount of infective blood injected into the pig. The following summary shows the relation between the quantity of virus injected, the average weight of the pigs treated and the average of the agglutination maximums.

Number of pigs.	Amount of virus injected.	Average weight.	Average agglutination, maximum.
7	1 cc	30 lbs	1-197
2	2 cc	36 lbs	No reaction.
26	5 cc	66 lbs	1-288
16	8 cc	72 lbs	1-362
12	9 cc	61 lbs	1-500
13	10 cc	81 lbs	1-392

*Which is in a general way equivalent to age in the pigs here considered.

This summary shows the tendency toward an increase in agglutinative power of blood from heavier hogs in addition to demonstrating the increased agglutinative power as a result of increased dose of virus.

It might be supposed, with reason, that the source of the virus used for treating the pigs would influence the production of agglutinins in the treated pig. It is a point having little force in this connection, since all the virus used (except that on Expt. 291) had the same source, viz. the "Ames virus." The only difference in these virus depends upon the variation in their passage through pigs and in their age.

In all these cases the sample was secured after the pig died from the disease, or was killed. The number of days the pig lived after injection of the virus seems to bear no constant relation to the agglutinative power of the pig's blood serum. Except in those cases where the pig died, it may be assumed that the pig was killed at the height of the disease. We have no data on the rate of increase of the agglutinin after treatment of individual pigs. We learn very little by comparing the reaction of the blood of pigs that died with those that were killed.

REACTIONS WITH THE BLOOD OF PIGS TREATED WITH "MIXED SERUM."

Table III shows the data connected with the testing of blood from 49 pigs treated simultaneously with hog cholera serum and virus. The important features of this table in addition to the agglutination re-

TABLE III.—*Agglutination tests with Culture "Virus 36" and blood of pigs treated with mixed Sera.*

Dilution of serum.						50.		100.		125.		250.		500.	
No. of pig.	Date sample drawn.	Results of treatment.	Date treated.	Virus used on pig.	Serum used on pig.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
Expt. 293....	1-25-10	Remained well............	11-18-09	1 cc. virus 124......	5 cc. M. S. 46............	+	—	—	—	—	—	—	—	0	0
Expt. 294....	1-25-10	Remained well............	11-18-09	1 cc. virus 124......	10 cc. M. S. 46............	—	—	—	—	—	—	0	0	0	0
Expt. 295....	1-25-10	Remained well............	11-18-09	1 cc. virus 124......	15 cc. M. S. 46............	—	—	—	—	0	0	0	0	0	0
Expt. 296....	1-25-10	Remained well............	11-18-09	1 cc. virus 124......	20 cc. M. S. 46............	—	—	—	—	—	—	0	0	0	0
Expt. 297....	1-25-10	Remained well............	11-18-09	1 cc. virus 124......	25 cc. M. S. 46............	—	—	—	—	—	—	—	—	0	0
Expt. 299....	12- 1-09	Pig died in 12 days........	11-19-09	1 cc. virus 124......	5 cc. M. S. 47............	0	0	0	0	0	0	0	0	0	0
Expt. 300....	1-21-10	Remained well............	11-19-09	1 cc. virus 124......	10 cc. M. S. 47............	+	—	+	—	—	—	—	—	—	—
Expt. 302....	1-21-10	Died 1-21-10, not posted...	11-19-09	1 cc. virus 124......	20 cc. M. S. 47............	—	—	—	—	—	—	—	—	—	—
Expt. 303....	1-21-10	Remained well............	11-19-09	1 cc. virus 124......	25 cc. M. S. 47............	+	+	+	—	+	—	—	—	—	—
Expt. 307....	1-21-10	Remained well............	11-29-09	1 cc. virus 127......	15 cc. M. S. 35............	+	—	+	—	—	—	—	—	—	—
Expt. 308....	1-21-10	Remained well............	11-29-09	1 cc. virus 127......	20 cc. M. S. 35............	+	+	—	—	—	—	—	—	—	—
Expt. 309....	1-21-10	Remained well............	11-29-09	1 cc. virus 127......	25 cc. M. S. 35............	+	—	—	—	—	—	0	0	0	0
Expt. 312....	1-21-10	Remained well............	11-30-09	1 cc. virus 128......	10 cc. M. S. 41............	—	—	0	0	0	0	0	0	0	0
Expt. 313....	1-21-10	Remained well............	11-30-09	1 cc. virus 128......	15 cc. M. S. 41............	—	—	0	0	0	0	0	0	0	0
Expt. 314....	1-21-10	Remained well............	11-30-09	1 cc. virus 128......	20 cc. M. S. 41............	+	—	+	—	+	—	—	—	—	—
Expt. 315....	1-21-10	Remained well............	11-30-09	1 cc. virus 128......	25 cc. M. S. 41............	+	+	+	+	+	+	—	—	—	—
Expt. 317....	1-18-10	Remained well............	12-15-09	2 cc. filt. virus 136...	10 cc. M. S. 35............	0	0	0	0	0	0	0	0	0	0
Expt. 318....	1-18-10	Remained well............	12-15-09	2 cc. filt. virus 136...	15 cc. M. S. 35............	+	—	—	—	—	—	—	—	0	0
Expt. 324....	1-18-10	Remained well............	12-29-09	1 cc. virus 124......	20 cc. M. S. 36............	+	—	—	—	—	—	0	0	0	0
Expt. 325....	1-18-10	Remained well............	12-29-09	1 cc. virus 124......	20 cc. M. S. 39............	+	—	—	—	—	—	—	—	—	—
Expt. 326....	1-18-10	Remained well............	12-29-09	1 cc. virus 124......	20 cc. M. S. 38............	+	+	—	—	—	—	—	—	—	—
Expt. 327....	1-18-10	Remained well............	12-29-09	1 cc. virus 124......	20 cc. M. S. 40............	+	—	—	—	—	—	—	—	—	—
Expt. 328....	1-18-10	Remained well............	12-29-19	1 cc. virus 124......	20 cc. M. S. 42............	+	—	—	—	—	—	—	—	—	—
Expt. 330....	1-25-10	Remained well............	1- 7-10	1 cc. virus 124......	20 cc. M. S. 48............	—	—	—	—	—	—	—	—	—	—
Expt. 331....	1-25-10	Remained well............	1- 7-10	1 cc. virus 124......	15 cc. M. S. 48............	+	+	+	+	—	—	—	—	—	—
Expt. 333....	1-25-10	Remained well............	1- 7-10	1 cc. virus 124......	25 cc. M. S. 48............	+	+	—	—	—	—	—	—	—	—
Expt. 335....	1-22-10	Died in 15 days, ulcers.....	1- 7-10	1 cc. virus 124......	5 cc. M. S. 49............	—	—	—	—	0	0	0	0	0	0
Expt. 336....	1-25-10	Alive but very thin........	1- 7-10	1 cc. virus 124......	10 cc. M. S. 49............	—	—	—	—	0	0	0	0	0	0
Expt. 337....	1-25-10	Remained well............	1- 7-10	1 cc. virus 124......	15 cc. M. S. 49............	+	+	+	+	+	—	—	—	—	—

TABLE III.—*Concluded.*

					Dilution of serum.	50.		100.		125.		250.		500.	
No. of pig.	Date sample drawn.	Results of treatment.	Date treated.	Virus used on pig.	Serum used on pig.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
Expt. 338	1-25-10	Remained well	1- 7-10	1 cc. virus 124	20 cc. M. S. 49	—	—	—	—	0	0	0	0	0	0
Expt. 339	1-25-10	Remained well	1- 7-10	1 cc. virus 124	25 cc. M. S. 49	—	—	—	—	0	0	0	0	0	0
Expt. 341	1-30-10	Died in 11 days, acute	1-19-10	1 cc. expt. 340	5 cc. M. S. 25	—	—	—	—	—	—	0	0	0	0
Expt. 345	1-31-10	Died in 12 days, acute	1-19-10	1 cc. expt. 340	10 cc. M. S. 32	—	—	0	0	0	0	0	0	0	0
Expt. 346	1-30-10	Died in 11 days, acute	1-19-10	1 cc. expt. 340	15 cc. M. S. 32	—	—	—	—	—	—	—	—	0	0
Expt. 347	2- 5-10	Died in 17 days, acute	1-19-10	1 cc. expt. 340	5 cc. M. S. 33	—	—	0	0	0	0	0	0	0	0
Expt. 348	2- 8-10	Died in 20 days, ulcers	1-19-10	1 cc. expt. 340	10 cc. M. S. 33	—	—	—	—	0	0	0	0	0	0
Expt. 349	1-30-10	Died in 11 days, ulcers	1-19-10	1 cc. expt. 340	15 cc. M. S. 33	—	—	—	—	—	—	—	—	—	—
Expt. 350	1-29-10	Died in 10 days, ulcers	1-19-10	1 cc. expt. 340	5 cc. M. S. 34	0	0	0	0	0	0	0	0	0	0
Expt. 351	1-31-10	Died in 12 days, ulcers	1-19-10	1 cc. expt. 340	10 cc. M. S. 34	—	—	0	0	0	0	0	0	0	0
Expt. 356	1-28-10	Died in 9 days, ulcers	1-19-10	1 cc. expt. 340	5 cc. M. S. 43	+	+	—	—	—	—	—	—	0	0
Expt. 363	1-25-10	Died in 6 days	1-19-10	1 cc. expt. 340	10 cc. M. S. 45	+	+	—	—	—	—	—	—	0	0
Expt. 365	1-30-10	Died in 9 days	1-21-10	1 cc. virus 122	10 cc. from virus 139	—	—	—	—	—	—	0	0	0	0
Expt. 373	2- 4-10	Died in 10 days	1-25-10	1 cc. virus 125	10 cc. M. S. 51	0	0	0	0	0	0	0	0	0	0
Expt. 374	2- 8-10	Died in 14 days	1-25-10	1 cc. virus 125	15 cc. M. S. 51	0	0	0	0	0	0	0	0	0	0
Expt. 381	2-16-10	Died in 9 days	2- 7-10	1 cc. virus 153	20 cc. M. S. 52	+	—	—	—	—	—	—	—	0	0
Expt. 405	5- 5-10	Died in 7 days, acute	4-28-10	1 cc. virus 170	10 cc. M. S. 56	0	0	0	0	0	0	0	0	0	0
Expt. 396	5- 5-10	Died in 8 days, acute	4-27-10	1 cc. virus 170	15 cc. from expt. 315	—	—	—	—	—	—	—	—	—	—
Expt. 395	5- 5-10	Died in 8 days, acute	4-27-10	1 cc. virus 170	10 cc. from expt. 315	+	—	—	—	—	—	—	—	—	—
Expt. 402	5-20-10	Died in 22 days	4-28-10	1 cc. virus 170	10 cc. M. S. 52	—	—	—	—	—	—	—	—	—	—

actions, are the amounts and sources of the sera and virus injected and the results of the treatment.

As for the agglutination reactions, it will be seen that

6 or 12.25 per cent gave no reaction at a dilution of 1—50.
5 or 10.20 per cent reacted at a dilution of 1—50.
6 or 12.25 per cent reacted at a dilution of 1—100.
6 or 12.25 per cent reacted at a dilution of 1—125.
7 or 14.28 per cent reacted at a dilution of 1—250.
19 or 38.77 per cent reacted at a dilution of 1—500.

These results correspond quite closely to those secured with virus blood. One might be tempted to conclude that the influence of the serum could not be detected in the agglutination reactions. It must be borne in mind that the average weight of the pigs in Table III is only 35 lbs. and also that they received only 1 cc. of virus each. Now we can make a fairer comparison of the agglutinative power of the blood serum of pigs treated with hog cholera virus only, and with hog cholera virus and serum simultaneously. The summary on page 417 shows that 7 pigs receiving 1 cc. virus each and weighing on an average of 30 lbs. reacted at an average dilution of 1-197. The average maximum reaction at which agglutination occurred with the blood of 49 pigs treated with both serum and virus is 1-262.

It will be of interest to note the difference in the agglutinative power of the blood from the pigs that were protected by the serum and from those that died. We have made this difference very readily perceptible in the following summary.

Dilution of serum.	Lived.		Died.	
	Number of pigs.	Percentage.	Number of pigs.	Percentage.
0	1	3.6	5	23.8
1- 50	2	7.1	3	14.3
1-100	4	14.3	2	9.5
1-125	4	14.3	2	9.5
1-250	3	10.7	4	19.1
1-500	14	50	5	23.8

A comparatively much larger number of pigs that die fail to show any agglutinative power in their serum, while the serum of a comparatively greater number of pigs that live gives a reaction at high dilution. In other words, it seems that with resistance or immunity we get increased agglutinative power; with susceptibility or absence of immunity, a less or no increase. This is in keeping with the deduction that heavier or older pigs (which are well known to be more resistant to cholera infection) have blood serum with a higher agglutinin content.

We can find no relation between the amount of protective serum injected into the pig and the production of agglutinins in the pig's blood.

REACTIONS WITH THE BLOOD OF HYPERIMMUNIZED PIGS.

This phase of the subject has received considerable attention. It has been our aim to determine the effect of repeated injections of virus blood and tail bleedings on the agglutinative power of the blood of "serum hogs."

We assume that the following factors influence the production of agglutinins in the body fluids:

TABLE IV.—*Showing agglutination reactions with blood from serum hog 136.*

Dilution of serum.			400.		[800.		1000.		2000.		4000.		8000.		10000.		12500.		25000.]		50000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
2100 cc.........	11-24-09	....	+	+	+	+	—	—	—	—	......	......	......	......	......	......	......	......	......	......	......	......
2100 cc.........	12- 1-09	First.........	+	+	+	+	+	+	+	+	+	—	......	......	......	......	......	......	......	......	......	......
2100 cc.........	12- 8-09	Second.......	......	......	......	......	+	+	+	+	+	+	+	+	+	+	+	+	......	......	......	......
2100 cc.........	12-15-09	Third........	+	+	+	+	+	+	+	+	+	+	+	+	+	—	—	—	—	—	—	—
2400 cc.........	12-22-09	Fourth.......	......	......	......	......	......	......	......	......	......	......	......	......	—	—	—	—	—	—	—	—
2700 cc.........	12-29-09	Fifth.........	......	......	......	......	......	......	......	......	+	+	+	—	+	—	+	—	—	—	—	—
2700 cc.........	1- 5-09	Killed........	......	......	......	......	......	......	......	......	+	+	+	+	+	—	+	—	+	—	—	—
Mixed serum 48..	....	....	......	......	......	......	......	......	......	......	+	+	+	—	—	—	—	—	—	—	—	—
Tested.	Date drawn.	Preservative.																				
2-21-10.........	12-15-09	.5% phenol....	......	......	+	—	+	—	+	—	+	—	—	—	......	......	......	......	......	......	......	......
2-21-10.........	12-15-09	.5% trilsuce...	......	......	+	—	+	—	+	—	+	—	—	—	......	......	......	......	......	......	......	......
2-21-10.........	12-15-09	.2% formol....	......	......	+	—	+	—	+	—	+	—	—	—	......	......	......	......	......	......	......	......
2-21-10.........	12-15-09	.5% fromol....	......	......	+	—	+	—	+	—	+	—	—	—	......	......	......	......	......	......	......	......

TABLE V.—*Showing agglutination reactions with blood from serum hog 138.*

Dilution of serum.			400.		800.		1000.		2000.		4000.		8000.		10000.		12500.		25000.		50000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment
800 cc......	11-22-09	....	+	+	+	+	+	+	—	—	—	......	......	......	......	......	......	......	......	......	......	......
1200 cc.....	11-26-09	....	+	+	+	—	+	—	—	—	0	0	......	......	......	......	......	......	......	......	......	......
1700 cc.......	12- 3-09	....	......	......	......	......	......	......	......	......	+	—	—	—	—	—	—	—	......	......	......	......
2300 cc......	12-10-09	First.........	+	+	+	+	+	+	+	—	—	—	......	......	......	......	......	......	......	......	......	......
2300 cc......	12-17-09	Second.......	+	—	+	—	+	—	+	—	—	—	......	......	......	......	......	......	......	......	......	......
2300 cc.......	12-24-09	Third........	+	—	+	—	—	—	—	—	—	—	......	......	......	......	......	......	......	......	......	......
2300 cc.......	12-31-09	Fourth.......	+	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0
2600 cc.......	1-19-09	Fifth.......	......	......	+	—	+	—	+	—	—	—		—	......	......	......	......	......	......	......	......
2600 cc.........	1-27-10	Killed........	......	......	+	—	+	—	+	—	—	—	—	—	......	......	......	......	......	......	......	......
Mixed serum 52..	....	....					......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......

TABLE VI.—*Showing agglutination reactions with blood from serum hog 137.*

Dilution of serum.			400.		800.		1000.		2000.		4000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
900 cc	11-22-09	....	—	—	0	0	0	0	0	0	......	......
1300 cc	11-26-09	....	—	—	0	0	0	0	0	0	0	0
2250 cc	12-10-09	First	—	—	—	—	—	—	—	—	0	0
2250 cc	12-17-09	Second	+	—	—	—	—	—	—	—	—	—
2550 cc	12-24-09	Third	—	—	—	—	—	—	—	—	0	0
2965 cc	12-31-10	Fourth	+	—	+	—	—	—	—	—	—	—
3265 cc	1- 7 10	Fifth	+	—	—	—	—	—	—	—	0	0
3265 cc	1 14-10	Sixth	+	—	—	—	—	—	—	—	0	0
3265 cc	1-21-10	Seventh	+	—	—	—	—	—	0	0	0	0
3265 cc	1-28-10	Killed	+	—	—	—	—	—	—	—	—	—
Mixed serum 53	....	....	+	+	—	—	—	—	—	—	—	—

TABLE VII.—*Showing agglutination reactions with blood from serum hog 139.*

Dilution of serum.			400.		800.		1000.		2000.		4000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
2000 cc	11-24-09	....	—	—	0	0	0	0	0	0	......	......
2000 cc	12- 1-09	First	—	—	—	—	—	—	0	0	......	......
2000 cc	12- 8-09	Second	—	—	0	0	0	0	0	0	......	......
2000 cc	12-15-09	Third	—	—	—	—	—	—	—	—	—	—
2300 cc	12-22-09	Fourth	+	—	—	—	—	—	0	0	0	0
2600 cc	12-29-09	Fifth	—	—	—	—	0	0	0	0	0	0
2600 cc	1- 5-10	Killed	—	—	—	—	—	—	0	0	0	0
Mixed serum 49	....	....	+	—	—	—	—	—	—	—	0	0

TABLE VIII.—*Showing agglutination reactions with blood from serum hog 140.*

Dilution of serum.			400.		800.		1000.		2000.		4000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
1270 cc	10-16-09	First	......	......	—	—	—	—	—	—	0	0
1420 cc	10-23-09	Second	......	......	—	—	—	—	0	0	0	0
1420 cc	10-30-09	Third	......	......	—	—	—	—	0	0	0	0
1420 cc	11- 6-09	Killed	......	......	—	—	—	—	0	0	0	0
Mixed serum 46	....	....	—	—	—	—	0	0	0	0	0	0

TABLE IX.—*Showing agglutination reactions with blood from serum hog 141.*

Dilution of serum.			400.		800.		1000.		2000.		4000.		8000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
1460 cc......	10-16-09	First...	......	......	+	+	+	+	+	—	—	—	—	—
1660 cc......	10-23-09	Second.	......	......	+	+	+	+	+	+	—	—	—	—
1660 cc......	10-30-09	Third..	......	......	+	+	+	+	+	+	—	—	—	—
1660 cc......	11- 6-09	Killed..	......	......	+	+	+	+	+	+	—	—	0	0
Mixed serum 47........	....	....	+	+	+	+	—	—	—	—	—	—	......	......

TABLE X.—*Showing agglutination reactions with blood from serum hog 144.*

Dilution of serum.			400.		800.		1000.		2000.		4000.		8000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
50 cc......	12-22-09	....	0	0	0	0	0	0	0	0	0	0	......	......
250 cc......	12- 3-09	....	0	0	0	0	0	0	0	0	0	0	......	......
940 cc......	12-17-09	....	+	+	+	+	—	—	—	—	—	—	......	......
1790 cc......	12-30-09	First...	+	+	—	—	—	—	—	—	—	—	......	......
1790 cc......	1- 6-10	Second.	+	+	—	—	—	—	—	—	0	0	......	......
1790 cc......	1-13-10	Third..	+	—	—	—	—	—	—	—	0	0	......	......
1790 cc......	1-20-10	Killed..	+	—	—	—	—	—	—	—	0	0	......	......
Mixed serum 50........	....	....	+	—	—	—	—	—	—	—	0	0	......	......

TABLE XI.—*Showing agglutination reactions with blood from serum hog 143.*

Dilution of serum.			400.		800.		1000.		2000.		4000.		8000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
50 cc......	11-22-09	....	0	0	0	0	0	0	0	0	......	......	......	......
250 cc......	11-26-09	....	0	0	0	0	0	0	0	0	......	......	......	......
1602 cc......	1-14-10	First...	+	+	+	—	+	—	—	—	—	—	......	......
1602 cc......	1-21-10	Second.	+	—	—	—	—	—	—	—	—	—	......	......
1602 cc......	1-28-10	Third..	+	—	—	—	—	—	—	—	—	—	......	......
1602 cc......	2- 4-10	Killed..	—	—	—	—	—	—	—	—	0	0	......	......
Mixed serum 54........	....	....	+	—	—	—	—	—	—	—	0	0	......	......
Mixed serum 54a.......	....	....	+	—	—	—	—	—	—	—	0	0	......	......

TABLE XII.—*Showing agglutination reactions with blood from serum hog 149.*

Amount of virus injected into pig.	Date of drawing sample.	Tail of other bleeding.	400. Agglutination.	400. Sediment.	800. Agglutination.	800. Sediment.	1000. Agglutination.	1000. Sediment.	2000. Agglutination.	2000. Sediment.	4000. Agglutination.	4000. Sediment.	5000. Agglutination.	5000. Sediment.	10000. Agglutination.	10000. Sediment.	12500. Agglutination.	12500. Sediment.	25000. Agglutination.	25000. Sediment.	50000. Agglutination.	50000. Sediment.
1425 cc........	4-30-10	Second........	+	+	+	+	+	+	+	—	—	—	......	......	......	......	......	......	......	......	......	......
1425 cc........	5- 9-10	Third........	+	+	+	+	+	+	+	+	+	+	+	—	+	—	—	—	—	—	—	—
1625 cc........	5-16-10	Fourth........	......	......	......	......	......	......	......	......	......	......	+	—	—	—	—	—	—	—	—	—
1725 cc........	5-23-10	Fifth........	......	......	......	......	......	......	......	......	......	......	+	—	—	—	—	—	—	—	0	0
1725 cc........	5-31-10	Killed........	......	......	......	......	......	......	......	......	......	......	+	—	—	—	+	—	—	—	0	0
Mixed serum 60..	....	....	......	......	......	......	......	......	......	......	......	......	+	—	+	—	+	—	—	—	—	—

TABLE XIII.—*Showing agglutination reactions with blood from serum hog 145.*

Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	400. Agglutination.	400. Sediment.	800. Agglutination.	800. Sediment.	1000. Agglutination.	1000. Sediment.	2000. Agglutination.	2000. Sediment.	4000. Agglutination.	4000. Sediment.	5000. Agglutination.	5000. Sediment.	10000. Agglutination.	10000. Sediment.	12500. Agglutination.	12500. Sediment.	25000. Agglutination.	25000. Sediment.	50000. Agglutination.	50000. Sediment.
50 cc........	11-22-09	....	—	—	0	0	0	0	0	0	......	......	......	......	......	......	......	......	......	......	......	......
250 cc........	12- 3-09	....	—	—	0	0	0	0	0	0	0	0	......	......	......	......	......	......	......	......	......	......
725 cc........	12- 9-09	....	—	—	—	—	—	—	0	0	0	0	......	......	......	......	......	......	......	......	......	......
1175 cc........	12-13-09	....	—	—	—	—	—	—	—	—	—	—	......	......	......	......	......	......	......	......	......	......
1750 cc........	12-20-09	First........	+	—	+	—	+	—	+	—	—	—	......	......	......	......	......	......	......	......	......	......
1750 cc........	12-27-09	Second........	+	+	+	+	+	+	+	—	—	—	......	......	......	......	......	......	......	......	......	......
1750 cc........	1- 3-09	Third........	+	—	+	—	—	—	—	—	—	—	......	......	......	......	......	......	......	......	......	......
1750 cc........	1-10-10	Fourth........	+	—	—	—	—	—	—	—	0	0	......	......	......	......	......	......	......	......	......	......
2050 cc........	1-17-10	Fifth........	+	—	+	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
2050 cc........	1-24-10	Killed........	+	—	+	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0
Mixed serum 51..	....	....	+	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	0	0	0	0

TABLE XIV.—*Showing agglutination reactions with blood from serum hog 150.*

Dilution of serum.			400.		800.		1000.		2000.		4000.		5000.		10000.		12500.		25000.		50000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
1225 cc....	4-23-10	First..	+	—	—	—	—	—	—	—	—	—	...	...	...	...	...	...	...	...	...	...
1425 cc.........	4-30-10	Second.......	+	+	+	—	—	—	—	—	—	—	...	...	...	...	...	...	...	...	...	...
1425 cc.........	5- 9-10	Third........	+	+	+	+	+	+	+	+	+	+	+	—	+	—	+	—	+	—	—	—
1625 cc.........	5-16-10	Killed........	...	...	...	...	...	...	...	...	...	...	+	—	+	—	+	—	+	—	—	—
Mixed serum 59..	....	....	...	...	...	...	...	...	...	...	...	...	+	—	+	—	+	—	+	—	+	—

TABLE XV.—*Showing agglutination reactions with blood from serum hog 147.*

Dilution of serum.			400.		800.		1000.		2000.		4000.		5000.		10000.		12500.		25000.		50000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
1830 cc.........	3-28-10	First.........	+	+	+	+	+	+	+	+	+	+	+	+	—	—	—	—	—	—	—	—
1830 cc.........	4- 4-10	Second.......	+	+	+	+	+	+	+	+	+	+	+	+	—	—	—	—	—	—	—	—
1830 cc.........	4-11-10	Third.......	...	...	...	...	...	...	...	...	...	...	+	+	—	—	—	—	—	—	—	—
1830 cc.........	4-18-10	Fourth.......	...	...	...	...	...	...	...	...	...	...	+	+	—	—	—	—	—	—	—	—
2130 cc.........	4-25-10	Fifth.........	...	...	...	...	...	...	...	...	...	...	+	—	—	—	—	—	—	—	—	—
2430 cc.........	5- 2-10	Sixth........	...	...	...	...	...	...	...	...	...	...	+	—	—	—	—	—	—	—	—	—
2430 cc.........	5-10-10	Killed.......	...	...	...	...	...	...	...	...	...	...	+	—	+	—	—	—	—	—	—	—
Mixed serum 57..	....	....	...	...	...	...	...	...	...	...	...	...	+	—	+	—	+	—	+	—	—	—

TABLE XVI.—*Showing agglutination reactions with blood from serum hog 146.*

Dilution of serum.			400.		800.		1000.		2000.		4000.		5000.		10000.		12500.		25000.		50000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
50 cc.........	11-22-09	....	+	+	—	—	—	—	—	—	......	......	......	......	......	......	......	......	......	......	......	......
200 cc.........	12- 3-09	....	+	—	+	—	—	—	0	0	0	0	......	......	......	......	......	......	......	......	......	......
1725 cc.........	1-21-10	First.........	+	—	+	—	+	—	—	—	—	—	—	—	—	—	—	—	0	0	0	0
1725 cc.........	1-28-10	Second.......	—	......	+	—	+	—	+	—	—	—	—	—	—	—	......	......	......	......	......	......
1725 cc.........	2- 4-10	Third.........	......	......	+	—	—	—	—	—	—	—	—	—	—	—	......	......	......	......	......	......
1725 cc.........	2-11-10	Fourth.......	......	......	+	—	+	—	+	—	+	—	—	—	—	—	......	......	......	......	......	......
2027 cc.........	2-18-10	Killed........	......	......	+	—	+	—	+	—	+	—	+	—	—	—	......	......	......	......	......	......
Mixed serum 55..	....	....	......	......	+	—	+	—	+	—	+	—	+	—	—	—	......	......	......	......	......	......

TABLE XVII.—*Showing agglutination reactions with blood from serum hog 151.*

Dilution of serum.			400.		800.		1000.		2000.		4000.		5000.		10000.		12500.		25000.		50000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination	Sediment.
1350 cc.........	4-30-10	Second.......	+	—	—	—	—	—	—	—	—	—	......	......	......	......	......	......	......	......	......	......
1350 cc.........	5- 9-10	Third........	+	+	+	+	+	+	+	+	+	+	+	—	—	—	—	—	—	—	—	—
1550 cc.........	5-16-10	Fourth.......	......	......	......	......	......	......	......	......	......	......	—	—	—	—	—	—	—	—	0	0
1850 cc.........	5-23-10	Fifth........	......	......	......	......	......	......	......	......	......	......	+	—	—	—	—	—	—	—	0	0
1850 cc.........	5-31-10	Sixth........	......	......	......	......	......	......	......	......	......	......	+	—	—	—	—	—	—	—	0	0
1975 cc.........	6- 8-10	Killed.......	......	......	......	......	......	......	......	......	......	......	+	+	—	—	—	—	—	—	—	—
Mixed serum 61..	....	....	......	......	......	......	......	......	......	......	......	......	+	—	—	—	—	—	—	—	—	—

TABLE XVIII.—*Showing agglutination reactions with blood from serum hog 148.*

Dilution of serum.			2000.		4000.		5000.		10000.		12500.		25000.		50000.		100000.		125000.		500000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
2320 cc.........	3-22-10	First.........	+	+	+	+	+	—	—	—	—	—	—	—	—	—	......	......	......	......	......	......
2320 cc.........	3-29-10	Second.......	......	......	......	......	+	—	—	—	—	—	—	—	—	—	......	......	......	......	......	......
2320 cc.........	4- 5-10	Third.........	......	......	......	......	+	—	—	—	—	—	—	—	—	—	......	......	......	......	......	......
2320 cc.........	4-12-10	Fourth.......	......	......	......	......	+	+	—	—	—	—	—	—	—	—	......	......	......	......	......	......
2320 cc.........	4-18-10	Fifth.........	......	......	......	......	+	—	—	—	—	—	—	—	—	—	......	......	......	......	......	......
2620 cc.........	4-25-10	Sixth.........	......	......	......	......	+	—	—	—	—	—	—	—	—	—	......	......	......	......	......	......
2920 cc.........	5- 2-10	Seventh......	......	......	......	......	......	......	......	......	......	......	......	......	+	—	—	—	0	0	......	......
2920 cc.........	5-10-10	Killed........	......	......	......	......	......	......	......	......	......	......	......	......	+	—	—	—	—	—	0	0
Mixed serum 58..	....	....	......	......	......	......	+	—	+	—	+	—	—	—	—	—	......	......	......	......	......	......

TABLE XIX.—*Showing agglutination reactions with blood from serum hog 152.*

Dilution of serum.			400.		800.		1000.		2000.		4000.		5000.		10000.		12500.		25000.		50000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
1250 cc.........	4-23-10	First.........	+	—	—	—	—	—	—	—	—	—	......	......	......	......	......	......	......	......	......	......
1450 cc.........	4-30-10	Second.......	+	+	+	+	+	—	—	—	—	—	......	......	......	......	......	......	......	......	......	......
1450 cc.........	5- 9-10	Third.........	+	+	+	+	+	+	+	—	+	—	+	—	+	—	—	—	—	—	—	—
1650 cc.........	5-16-10	Fourth.......	......	......	......	......	......	......	......	......	......	......	+	—	—	—	—	—	—	—	—	—
1750 cc.........	5-23-10	Fifth.........	......	......	......	......	......	......	......	......	......	......	+	—	+	—	—	—	—	—	—	—
1750 cc.........	5-31-10	Killed........	......	......	......	......	......	......	......	......	......	......	+	—	—	—	—	—	—	—	—	—
Mixed serum 62..	....	....	......	......	......	......	......	......	......	......	......	......	+	—	+	—	+	—	—	—	—	—

TABLE XX.—*Showing agglutination reactions with blood from serum hog 155.*

Dilution of serum.			400.		800.		1000.		2000.		4000.		8000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
1115 cc.....	5-28-10	First...	+	—	—	—	—	—	—	—	—	—	......	......
1115 cc.....	6- 4-10	Second.	+	+	+	+	+	+	—	—	—	—	......	......
1295 cc.....	6-11-10	Third..	+	+	+	+	+	+	—	—	—	—	......	......
1295 cc.....	6-18-10	Killed..	......	......	+	—	—	—	—	—	—	—	0	0
Mixed serum 63	....	....	+	+	+	+	+	—	+	—	—	—	......	......

TABLE XXI.—*Showing agglutination reactions with blood from serum hog 157.*

Dilution of serum.			400.		800.		1000.		2000.		4000.		8000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
1490 cc.....	6- 2-10	First...	+	—	+	—	+	—	—	—	—	—	......	......
1490 cc.....	6- 9-10	Second.	+	+	+	+	+	+	+	+	—	—	......	......
1490 cc.....	6-16-10	Third..	+	+	+	+	+	+	—	—	—	—	......	......
1690 cc.....	6-23-10	Killed..	......	......	+	—	—	—	—	—	—	—	0	0
Mixed serum 64........	....	....	+	+	+	—	+	—	—	—	—	—	......	......

TABLE XXII.—*Showing agglutination reactions with blood from serum hog 158.*

Dilution of serum.			400.		800.		1000.		2000.		4000.		8000.	
Amount of virus injected into pig.	Date of drawing sample.	Tail or other bleeding.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
1325 cc.....	6- 2-10	First...	+	—	+	—	+	—	+	—	—	—	......	......
1325 cc.....	6- 9-10	Second.	+	+	+	+	+	+	+	+	—	—	......	......
1325 cc.....	6-16-10	Third..	+	+	+	+	+	+	+	+	—	—	......	......
1525 cc.....	6-23-10	Killed..	+	—	+	—	—	—	—	—	—	—	......	......
Mixed serum 65 . .	. . . .	. . .	+	+	+	+	+	—	+	—	—	—		

1. The nature of the substance or agglutinogen introduced into the body.

2. The amount of agglutinogen introduced.

3. The number of injections and the length of time required to introduce the total amount of agglutinogen.

4. The method of introducing the agglutinogen.

5. Idiosyncrasy or individual variation in the body receiving the agglutinogen.

There may be many other influencing factors. The agglutination titer of any sample of blood serum depends to a great extent upon the time it is drawn relative to the time of treatment of the animal. Other factors influence the agglutinative power of a sample of serum after it is drawn, such as age, temperature and light. These can be easily controlled.

Of the factors above enumerated which influence the production of agglutinins in the body the first four are subject to control, the individual variation in animals only, being beyond our control. As an illustration of this last point we may say that if we take two pigs of the same sex and litter and as nearly alike as conceivable and subject these pigs to identical treatment in so far as factors 1, 2, 3, and 4 are concerned, we may not get identical results when we test samples of their blood for agglutinative power.

The 19 pigs furnishing the basis of the work outlined in Tables IV to XXII varied greatly in weight, breeding and other characteristics. We could not expect them to respond identically to identical treatment even were there no question of idiosyncrasy. As a matter of fact, the treatment of these pigs has been variable both as regards factors, 1, 2, 3 and 4 (considered above) and as regards withdrawal of blood for agglutination tests or other purposes. A comparison of the results secured from a study of Tables IV to XXIII is, therefore, very difficult.

There is a considerable variation in the maximum dilutions at which agglutination occurred.

Of the 19 cases studied,

1 or 5.26 per cent gave a maximum reaction at 1—2,000.
7 or 36.85 per cent gave a maximum reaction at 1—4,000.
1 or 5.26 per cent gave a maximum reaction at 1—8,000.
2 or 10.52 per cent gave a maximum reaction at 1—12,500.
1 or 5.26 per cent gave a maximum reaction at 1—25,000.
7 or 36.85 per cent gave a reaction at 1—50,000.

It is apparent that a little less than half of the maximum reactions are at one extreme, 200 to 4,000; and a little less than half at the other extreme, 25,000 to 50,000, with a few cases between these extremes.

A study of one case will illustrate what might be called a typical response to several influencing factors, such as increasing the total of virus injected and repeated bleedings.

Serum hog 145 (Table XIII) wt. 56 lbs., July 17, 1909, received 30 cc. mixed serum, 30, and 1 cc. virus 107. The weight increased to 150 lbs. during the following treatment:

Date of test.	Amount of virus injected to date.	Maximum dilution at which agglutination occurred.	Bleeding.
11-22-09	50 cc.	1-400	5 cc. from tail.
12- 3-09	250 cc.	1-400	5 cc. from tail.
12- 9-09	725 cc.	1-1000	5 cc. from tail.
12-13-09	1175 cc.	1-4000	5 cc. from tail.
12-20-09	1175 cc.	1-4000	First tail.
12-27-09	1750 cc.	1-4000	Second tail.
1- 3-10	1750 cc.	1-4000	Third tail.
1-10-10	1750 cc.	1-2000	Fourth tail.
1-17-10	2050 cc.	1-50,000	Fifth tail.
1-24-10	2050 cc.	1-25,000	Killed.
1-30-10	2050 cc.	1-12,500	Mixed 1—6.

A total injection of 50 cc. caused a reaction at 1-400; an increase of 200 cc. produces no change. A total of 725 cc. gives a reaction at 1-1,000, while a total of 1175 cc. results in a reaction at 1-4000 which is maintained until the first bleeding. An increase of 575 cc. produces no change in the agglutinative reaction for the second and third bleedings and results in a fall to 1-2000 at the fourth bleeding. Another injection of 300 cc. brings the reaction up to 1-50,000 but at the last bleeding it falls to 1-25,000. The reaction produced by a mixture of the different bleedings is about an average of the reactions for all.

The increase in virus injected seems to result in an increase (not necessarily *pari passu*) in the agglutinin content of the serum. The withdrawal of a considerable amount of blood tends to produce a decrease in the agglutinin content which may or may not be offset by virus injections. It is true that the response is very irregular as can be seen by studying the tables.

It is not maintained that it is the blood injected or the ultravisible virus that stimulates the production of agglutinins but the *B. cholerae suis* in the blood. In other words we assume that it is the number of *B. cholerae suis* in a quantity of virus and not the volume that affects the agglutinin production in the treated pig.

Unfortunately we were not in a position to make bacterial counts of any great number of samples of virus. We have not found above 10,000 bacteria per cc. in fresh virus. If all these organisms were *B. cholerae suis* the total number in 3,000 cc. of virus would be 30,000,000. We have estimated (by a number of platings) that 1 cc. of a 24 hour bouillon culture of *B. cholerae suis* contains about 500,000,000 bacteria. We have not used so much as 3,000 cc. of virus on any of the 19 cases studied, therefore we have probably not injected more *B. cholerae suis* than would be found in .10 cc. of a 24 hour bouillon culture.

In one case we found that the injection of 10 cc. of a 24 hour bouillon culture of *B. cholerae suis* "virus 136" resulted in a serum giving a

maximum reaction at 1-500. In another case after an injection of 450 cc. of bouillon cultures 15 to 20 hours old mixed with 915 cc. normal pig blood an agglutination reaction was secured at a maximum of 1-25,000. In this case we probably introduced approximately 225 billions of living *B. cholerae suis* or about 7,500 times as many as injected into any of the seven cases, (in Tables IV to XXIII) that reacted at 1-50,000.

It is our belief that the number of *B. cholerae suis* increases greatly locally in the tissues of the injected pig, thus furnishing the agglutinogen in great amount. This belief is strengthened by the almost constant presence of the so-called *B. cholerae suis* abscesses in serum hogs treated intramuscularly.

AGGLUTINATION REACTIONS WITH MIXED SERA.

The term "mixed serum" in this paper is applied to a mixture of all the bleedings from one serum hog. Table XXIII shows the agglutination reactions with 51 samples of mixed sera. These tests were made at a variable length of time after drawing the blood and mixing it. Table XXIV shows retests with 25 of these samples and with a mixture of several others (m. s. 56).

Excepting the mixed sera and the four samples in Table IV, all the tests have been made with fresh serum separated from the corpuscles in defibrinated blood, without the addition of a preservative. All the samples in Tables XXIII and XXIV were defibrinated blood preserved in .5 per cent. phenol (10 cc. 5 per cent. phenol to 90 cc. defibrinated blood) except mixed serum 54a which was preserved by the addition of .5 cc. trikresol to 99.5 cc. defibrinated blood. The mixed sera were kept in cold storage at 6°-15° C.

Table XXIII shows that out of 51 mixed sera tested,

3 or 5.88 per cent did not agglutinate at 1—400.
3 or 5.88 per cent agglutinated at 1—400.
3 or 5.88 per cent agglutinated at 1—800.
2 or 3.92 per cent agglutinated at 1—1,000.
10 or 19.60 per cent agglutinated at 1—2,000.
12 or 23.52 per cent agglutinated at 1—4,000.
1 or 1.96 per cent agglutinated at 1—5,000.
4 or 7.84 per cent agglutinated at 1—8,000.
6 or 11.76 per cent agglutinated at 1—12,000.
7 or 13.72 per cent agglutinated at 1—50,000.

The object in the retests was to determine to what extent diminution in agglutinins or agglutinative power takes place with age. It was thought that perhaps we might be able to throw some light upon the subject of diminution or weakening of antibodies in general, including the protective substances against hog cholera. We do not possess the records of any extensive biological tests that show how long the Dorset-Niles serum retains its potency.

TABLE XXIII.—*Showing agglutination reactions with mixed sera and culture "Virus 136."*

Dilution of serum.			400.		800.		1000.		1600.		2000.		3200.		4000.		5000.		8000.		10000.		12000.		12500.		25000.		50000.	
No. of serum.	Date of test.	Approximate age of serum.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
Mixed serum 15..	11-10-09	1 year........	+	+	—	—	0	0	....	....	0	0	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 16..	11-10-09	1 year........	0	0	0	0	0	0	....	....	0	0	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 17..	11-10-09	11 months......	+	+	—	—	—	—	....	....	—	—	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 18..	11-10-09	10 months......	+	+	+	—	—	—	....	....	—	—	—	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 19..	11-10-09	8 months......	—	—	0	0	0	0	....	....	0	0	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 20..	12- 1-09	9 months......	—	—	0	0	0	0	....	....	0	0	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 21..	12- 6-09	9 months......	+	—	—	—	—	—	....	....	—	—	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 22..	12- 1-09	9 months......	0	0	0	0	0	0	....	....	0	0	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 23..	12- 1-09	7 months......	+	+	+	—	+	—	....	....	—	—	....	....	—	—	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 24..	12- 1-09	7 months......	+	+	+	+	+	+	....	....	+	+	....	....	—	—	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 25..	12-1 -09	7 months......	+	+	+	+	+	+	....	....	—	—	....	....	—	—	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 26..	12- 6-09	5 months......	+	+	+	—	+	—	....	....	—	—	....	....	—	—	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 27..	12- 6-09	5 months......	+	+	—	—	—	—	....	....	—	—	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 28..	12- 6-09	5 months......	—	—	—	—	0	0	....	....	0	0	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 29..	12- 6-09	5 months......	—	—	—	—	—	—	....	....	—	—	....	....	—	—	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 30..	12- 2-09	5 months......	0	0	0	0	0	0	....	....	0	0	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 31..	12- 2-09	5 months......	+	—	0	0	0	0	....	....	0	0	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 32..	12- 2-09	5 months......	+	+	+	+	—	—	....	....	0	0	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 33..	12- 6-09	5 months......	+	+	+	+	+	+	....	....	+	—	....	....	—	—	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 34..	12- 6-09	5 months.....	—	—	—	—	—	—	....	....	—	—	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 35..	12- 0-09	1 month......	+	+	+	+	+	+	....	....	+	+	....	....	+	+	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 36..	12-24-09	2 months......	+	+	—	—	—	—	....	....	—	—	....	....	0	—	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 37..	12-29-09	2 months......	+	+	+	+	+	+	+	—	+	—	+	—	+	—	—	—	—	—	....	....	—	—	....	....	....	....	....	....
Mixed serum 38..	12-29-09	2 months......	+	+	+	+	+	+	+	+	+	+	+	+	+	+	—	—	—	—	....	....	0	0	....	....	....	....	....	....
Mixed serum 39..	12-24-09	2 months.....	+	—	—	—	—	—	....	....	0	0	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 40..	12-29-09	2 months......	+	+	+	+	+	+	+	+	+	+	—	—	—	—	—	—	—	—	....	....	0	0	....	....	....	....	....	....
Mixed serum 41..	11-22-09	2 months......	+	+	+	+	+	+	+	+	+	+	+	—	—	—	—	—	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 42..	12-29-09	2 months......	+	+	+	+	+	+	+	+	+	+	+	+	+	+	—	—	—	—	....	....	—	—	....	....	....	....	....	....
Mixed serum 43..	12-29-09	2 months......	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	—	—	....	....	—	—	....	....	....	....	....	....
Mixed serum 44..	12-29-09	2 months......	+	+	+	+	+	+	+	+	+	+	+	+	+	—	+	—	+	—	....	....	+	—	....	....	....	....	....	....

TABLE XXIII.—*Concluded.*

Dilution of serum.			400.		800.		1000.		1600.		2000.		3200.		4000.		5000.		8000.		10000.		12000.		12500.		25000.		50000.	
No. of serum.	Date of test.	Approximate age of serum.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
Mixed serum 45..	12- 9-09	2 months......	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	—	....	....	—	—	....	....	....	....	....	....
Mixed serum 46..	11-22-09	Few days.......	—	—	—	—	0	0	....	....	0	0	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 47..	11-22-09	Few days.......	+	+	+	+	+	+	....	....	+	—	....	....	—	—	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 48..	1-12-10	Few days.......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—	....	....	—	—	....	....	—	—	—	—	—	—
Mixed serum 49..	1-12-10	Few days.......	+	—	—	—	—	—	....	....	—	—	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 50..	1-31-10	Few days.......	+	—	—	—	—	—	....	....	—	—	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 51..	1-29-10	Few days.......	+	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	....	....	—	—	....	....	....	....	....	....
Mixed serum 52..	1-29-10	Few days.......	....	....	+	—	....	....	+	—	—	—	....	....	—	—	....	....	—	—	....	....	....	....	....	....	....	....	....	....
Mixed serum 53..	1-29-10	Few days.......	+	+	—	—	—	—	....	....	—	—	....	....	—	—	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 54..	2-13-10	Few days.......	+	—	—	—	—	—	....	....	—	—	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 54a.	2-13-10	Few days.......	+	—	—	—	—	—	....	....	—	—	....	....	0	0	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 55..	3- 7-10	Few days.......	....	....	+	+	....	....	+	—	+	—	....	....	—	—	....	....	—	—	....	....	....	....	....	....	....	....	....	....
Mixed serum 57..	7-22-10	2 months......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—	....	....	+	—	....	....	+	—	—	—	—	—
Mixed serum 58..	7-22-10	2 months......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—	....	....	+	—	....	....	+	—	—	—	—	—
Mixed serum 59..	7-22-10	2 months......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—	....	....	+	—	....	....	+	—	+	—	+	—
Mixed serum 60..	8-10-10	1 month.......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—	....	....	+	—	....	....	+	—	—	—	—	—
Mixed serum 61..	8-10-10	1 month.......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—	....	....	—	—	....	....	—	—	—	—	—	—
Mixed serum 62..	8-10-10	1 month.......	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—	....	....	+	—	....	....	+	—	—	—	—	—
Mixed serum 63..	8-10-10	1 month.......	+	+	+	+	+	—	....	....	+	—	....	....	—	—	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 64..	8-10-10	1 month.......	+	+	+	—	+	—	....	....	—	—	....	....	—	—	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 65..	8-10-10	1 month.......	+	—	+	—	+	—	....	....	+	—	....	....	—	—	....	....	....	....	....	....	....	....	....	....	....	....	....	....

In Table XXV there are found in parallel columns the results of the tests and subsequent retests of 25 mixed sera. Tables XXIII and XXIV show the dates of the respective tests and retests. It is seen that the retests were made 6-8 months after the first tests.

The retests show

In 7 cases no change in agglutinative power.
In 4 cases a 25 per cent decrease.
In 3 cases a 50 per cent decrease.
In 1 case a 68 per cent decrease.
In 5 cases a 75 per cent decrease.
In 1 case a 80 per cent decrease.
In 4 cases an apparent increase.

Any increase is probably only apparent. In case of mixed serum 30 the first test failed to establish a maximum showing only that it was less than 400. The first test with mixed serum 31 probably did not establish a maximum since no test was made between 400 and 800. The same is true with mixed sera 37 and 44 when no attempt was made to get a reaction above 1-12,000.

We have not found that the presence of carbolic acid, trikresol or formalin has any depressing effect upon either the agglutinative power or potency of hog cholera serum.

AGGLUTINATIVE POWER AND POTENCY.

The question as to whether we can turn the agglutination test to account in measuring the potency of serum is answered in Table XXV. It must be confessed that the answer is not very definite. Table XXV shows the agglutinative power of the sera and the results of the biological tests. There are given the different amounts of serum used, the weight of the pigs employed and the results. In all cases the serum was tested against 1 cc. of virulent hog cholera blood. The virulence of the blood was always determined by the use of check pigs corresponding in weight, thrift and origin to the test pigs.

It would be possible to pick out a number of cases of mixed sera that showed low agglutinative power and low potency, and it would be easy to pick out cases showing a high agglutinative power and high potency. If we could arrange all the cases under these two headings the matter would be answered very satisfactorily but we can find cases of low agglutinative power and high potency and those showing high agglutinative power and low potency.

TABLE XXIV.—*Showing Agglutination retests*

Dilution of serum.			50.		100.		125.		200.		250.		400.		500.		800.	
No. of serum.	Date of test.	Approximate age of serum.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
Mixed serum 15.	7-17-10	1 yr., 8 mos.	....	....	....	....	....	....	—	—	....	....	0	0	0	0	....	....
Mixed serum 17.	7-17-10	1 yr., 7 mos.	....	....	....	....	....	....	—	—	....	....	—	—	—	—	....	....
Mixed serum 18.	7-17-10	1 yr., 6 mos.	....	....	....	....	....	....	—	—	....	....	—	—	—	—	....	....
Mixed serum 21.	7-17-10	1 yr., 4 mos.	....	....	....	....	....	....	....	....	....	....	+	—	....	....	—	—
Mixed serum 23.	7-17-10	1 yr., 2 mos.	....	....	....	....	....	....	....	....	....	....	—	—	....	....	—	—
Mixed serum 30.	7-17-10	1 year.....	—	—	—	—	—	—	....	....	—	—	....	....	0	0	....	....
Mixed serum 31.	7-17-10	1 year.....	—	—	—	—	—	—	....	....	—	—	....	....	—	—	....	....
Mixed serum 36.	7-17-10	9 months...	....	....	....	....	....	....	+	—	....	....	—	—	—	—	....	....
Mixed serum 38.	7-17-10	9 months...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—
Mixed serum 39.	7-17-10	9 months...	....	....	....	....	....	....	+	—	....	....	—	—	—	—	....	....
Mixed serum 40.	7-17-10	9 months...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—
Mixed serum 42.	7-17-10	9 months...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—
Mixed serum 43.	7-17-10	9 months...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—
Mixed serum 37.	7-22-10	9 months...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 44.	7-22-10	9 months...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 45.	7-22-10	9 months...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 48.	7-22-10	6 months...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 49.	7-22-10	6 months...	....	....	....	....	....	....	....	....	....	....	—	—	....	....	—	—
Mixed serum 50.	7-22-10	6 months...	....	....	....	....	....	....	+	+	....	....	—	—	—	—	....	....
Mixed serum 51.	7-22-10	6 months...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Mixed serum 52.	7-22-10	6 months...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—
Mixed serum 53.	7-22-10	6 months...	....	....	....	....	....	....	....	....	....	....	—	—	....	....	—	—
Mixed serum 55.	7-22-10	4 months...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	+	—
Mixed serum 56*	7-22-10	1 year+....	....	....	....	....	....	....	—	—	....	....	—	—	—	—	....	....
Mixed serum 54.	8-10-10	6 months...	....	....	....	....	....	....	+	—	....	....	—	—	—	—	....	....
Mixed serum 54a	8-10-10	6 months...	....	....	....	....	....	....	—	—	....	....	—	—	—	—	....	....

*M. S. 56 is a mixture of m. sera 25, 32, 33 and 34 q. v. in table.

with mixed sera and culture "virus 136".

1000.		1600.		2000.		3200.		4000.		5000.		8000.		10000.		12500.		16000.		25000.		50000.	
Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.	Agglutination.	Sediment.
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TABLE XXV.—*Amount of serum required to protect pig against 1 cc. virus.*

Mixed serum.	Maximum dilution at which agglutination occurred. First test.	Second test.	Weight of pig.	5 cc. serum.	Weight of pig.	10 cc. serum.	Weight of pig.	15 cc. serum.	Weight of pig.	20 cc. serum.	Weight of pig.	25 cc. serum.	Weight of pig.	30 cc. serum.
15	800	200	15	Died	20	Died	20	Died	20	Died			20	Lived.
16	—400		15	Died	18	Died	20	Died	20	Died			20	Died.
17	2000	500	20	Died	20	Died	20	Lived	25	Lived			25	Lived.
18	2000	500			56	Died	60	Lived	60	Lived			65	Lived.
19	400				30	Died	30	Died	37	Lived	38	Died		
20	400				35	Died	39	Died	42	Died	43	Died		
21	2000	1000			28	Lived	27	Lived	30	Lived				
22	—400				15	Died	20	Died	20	Died	20	Died		
23	4000	800	26	Lived	24	Lived	24	Lived						
24	4000		24	Lived	22	Lived	22	Lived						
25	4000		13	Died	19	Died in 68 days	55	Died—not h. c.						
26	4000				29	Lived	23	Lived	26	Lived	18	Lived		
27	2000				22	Lived	26	Died	20	Lived	20	Lived		
28	800				23	Lived	27	Lived	21	Lived	27	Died in 43 days		
29	4000				38	Lived	46	Lived	32	Lived	26	Lived		
30	—400	250			25	Lived	34	Died	26	Lived	45	Lived		
31	400	500			27	Died	28	Lived	48	Lived	37	Lived		
32	1000		20	Died	18	Died	28	Died						
33	4000		23	Died, ascarides	20	Died, chronic	42	Died, ascarides						
34	2000		20	Died	21	Died	23	Died						
35	4000		49	Died	49	Died	48	Lived	44	Lived	44	Lived		
36	2000	2000							63	Lived				
37	12000	16000	16	Died	22	Lived	30	Lived						
38	8000	8000							53	Lived				
39	1000	1000							55	Lived				
40	8000	4000							51	Lived				
41	5000		55	Died	44	Lived	46	Lived	50	Lived	37	Lived		
42	12000	8000									48	Lived		
43	12000	8000	13	Died, chronic	19	Died in 63 days	26	Lived						
44	12000	16000	18	Died, chronic	35	Lived	36	Lived						

TABLE XXV.—*Concluded.*

Mixed serum.	Maximum dilution at which agglutination occurred. First test.	Second test.	Weight of pig.	5 cc. serum.	Weight of pig.	10 cc. serum.	Weight of pig.	15 cc. serum.	Weight of pig.	20 cc. serum.	Weight of pig.	25 cc. serum.	Weight of pig.	30 cc. serum.
45	12000	8000	16	Died, ascarides	19	Died, ascarides	20	Lived						
46	400		36	Lived	33	Lived	33	Lived	27	Lived	26	Lived		
47	4000		35	Died	42	Lived	35	Lived	32	Lived	28	Lived		
48	50000	10000	49	Died	54	Lived	55	Lived	72	Lived	50	Lived		
49	2000	800	34	Died	62	Lived	61	Lived	57	Lived	62	Lived		
50	2000	2000	33	Lived	34	Lived	37	Lived						
51	12000	8000			23	Died in 30 days	18	Died	17	Died				
52	8000	8000	12	Died, ascarides	18	Lived	18	Lived	15	Died, ascarides				
53	4000	1000	15	Died	16	Lived	19	Lived	16	Lived				
54	2000	2000			17	Lived	23	Lived	17	Died, chronic				
54a	2000	2000			28	Died, chronic	28	Lived	29	Lived				
55	8000	4000	38	Died	34	Lived	45	Lived	41	Lived	44	Lived		
56		2000			18	Died	21	Died	26	Died				
57	50000				22	Died	22	Lived	20	Lived				
58	50000				17	Lived	17	Lived	18	Lived				
59	50000				15	Lived	16	Lived	17	Lived				
60	50000				41	Lived	38	Lived						

The following are cases in point:

LOW AGGLUTINATIVE POWER, LOW POTENCY.

Serum.	Agglutinative power.	Potency.
Mixed serum 16	Below 1–400	30 cc. did not protect.
Mixed serum 19	1–400	25 cc. did not protect.
Mixed serum 20	1–400	25 cc. did not protect.
Mixed serum 22	Below 1–400	25 cc. did not protect.

HIGH AGGLUTINATIVE POWER, HIGH POTENCY.

Serum.	Agglutinative power.	Potency.
Mixed serum 48	1–50,000	10 cc. protects.
Mixed serum 57	1–50,000	15 cc. protects.
Mixed serum 58	1–50,000	10 cc. protects.
Mixed serum 59	1–50,000	10 cc. protects.
Mixed serum 60	1–50,000	10 cc. protects.

A conclusion based upon the above data would be misleading in that it would affirm the value of the agglutination test in determining the potency of the Dorset-Niles serum.

The following cases illustrate the possibility of error in estimating potency by agglutinative power:

LOW AGGLUTINATIVE POWER, HIGH POTENCY.

Serum.	Agglutinative power.	Potency.
Mixed serum 28	1–800	10 cc. protects.
Mixed serum 30	Below 1–400	20 cc. protects.
Mixed serum 31	1–500	15 cc. protects.
Mixed serum 46	1–400	5 cc. protects.

HIGH AGGLUTINATIVE POWER, LOW POTENCY.

Serum.	Agglutinative power.	Potency.
Mixed serum 25	1–4000	15 cc. did not protect.
Mixed serum 33	1–4000	15 cc. did not protect.
Mixed serum 34	1–2000	15 cc. did not protect.
Mixed serum 51	1–12000	20 cc. did not protect.
Mixed serum 56	1–2000	20 cc. did not protect.

On the whole, however, it is to be observed that a serum having a high agglutinative power can be expected to have a higher potency than a serum with low agglutinative power. By potency we mean that the serum was able to protect a small pig against 1 cc. of virulent hog cholera blood in doses not larger than usually recommended by those engaged in serum production.

It may be well to arrange the mixed sera according to their agglutinative power and potency.

Of those agglutinating at

1—50,000........	5 or 100 per cent were potent.
1—12,000........	5 or $83\frac{1}{3}$ per cent were potent.
	1 or $16\frac{2}{3}$ per cent was not potent.
1—8,000........	4 or 100 per cent were potent.
1—5,000........	1 or -100 per cent was potent.
1—4,000........	7 or 77 7-9 per cent were potent.
	2 or 22 2-9 per cent were not potent.
1—2,000........	8 or 80 per cent were potent.
	2 or 20 per cent were not potent.
1—1,000........	1 or 50 per cent was potent.
	1 or 50 per cent was not potent.
1—800	1 or 50 per cent was potent.
	1 or 50 per cent was not potent.
1—400	2 or 50 per cent were potent.
	2 or 50 per cent were not potent.
Less than.......	1 or 33 1-3 per cent was potent.
1—400	2 or 66 2-3 per cent were not potent.

Of all the mixed sera agglutinating at a dilution of 1-2,000 or above

85.71 per cent were potent.
14.28 per cent were not potent.

Of all the mixed sera agglutinating at a dilution of 1-1,000 or less.

45.45 per cent were potent.
54.54 per cent were not potent.

A very potent serum, such as mixed serum 46 requires only 5 cc. to protect a 36 lb. pig, yet agglutinates at only 1-400. Mixed serum 57 agglutinating at 1-50,000 requires that 15 cc. shall be injected to protect a 22 lb. pig.

After studying the matter very carefully, we have come to the conclusion that the biological test (using small pigs) is very uncertain. Our experience shows that potency may be indicated if pigs weighing 75 to 100 lbs. be used, while lack of potency may be indicated by the use of pigs just weaned. The involvement of ascarides, lung worms and unfavorable climatic or dietary conditions tend to make serum-testing on small pigs very unsatisfactory.

Potency as indicated by our biological tests is only a relative and more or less uncertain matter. Therefore, when we try to compare the results of an easily controlled in vitro test such as the agglutination reaction with a very elastic standard of in vivo testing confusion is sure to ensue. Moreover, we have to admit at the outset that we are dealing with an unknown quantity when we try to introduce *B. cholerae suis* into the subject of potency of serum. We have not yet found an answer to the all important question: "What has *B. cholerae suis* to do with

hog cholera?" Our work furnishes an answer that should serve to keep the subject still in the field for discussion. *B. cholerae suis* has *a great deal* to do with hog cholera and serum production but *what* and *how important* its connection is we cannot say.

Dammann and Stedefeder[1] have recently published the results of a series of researches carried on at the veterinary college at Hanover. They produced hog cholera with filtrates of blood and diseased organs of hog cholera pigs. From one outbreak they isolated an organism showing the morphological and most of the cultural and biological characters of *B. cholerae suis*. This organism they designated *B. suipestifer*, Voldagsen. They were not able to produce hog cholera by use of filtrates from pigs in this outbreak. Cultures of *B. suipestifer*, Voldagsen, fed in large doses produced a septicaemia and death in a few days; fed in small doses it produced a more marked diphtheritic enteritis. The culture injected could be recovered in all cases. Fatal results followed subcutaneous or intravenous injection of their *B. suipestifer*. They likewise succeeded in producing hog cholera (or a disease resembling it) by cohabitation of healthy swine with pigs infected artificially with *B. suipestifer*, Voldagsen, or with pigs naturally infected in the Voldagsen outbreak.

Their agglutination tests and biological tests indicate that *B. suipestifer,* Uhlenhuth, is closely related to *B. paratyphi B*, and that *B. suipestifer*, Voldagsen, is a distinct specific organism having high virulence and producing an epizootic swine disease answering to the descriptions of hog cholera.

They believe that there is sufficient difference in the pathology of the lesions to permit of distinguishing bacillary hog cholera from that produced by the ultravisible virus.

SUMMARY.

GENERAL.

B. cholerae suis is an easily isolated organism in a great many cases of hog cholera. Possibly it is present in all cases.

A living virus capable of producing hog cholera passes through the Chamberland filters that keep back any form of *B. cholerae suis* or other organisms capable of multiplying in vitro to the extent of being susceptible of demonstration.

B. cholerae suis is capable of producing a disease in pigs quite similar to natural hog cholera and to the disease produced by the filterable virus.

The protection offered by the Dorset-Niles serum against the filterable virus may also extend to virulent cultures of *B. cholerae suis.* Whether it is necessary to protect against *B. cholerae suis* in practice is not determined.

The relation of *B. cholerae suis* to the filterable virus or to natural outbreaks of hog cholera is not determined by our work or to our satisfaction by the researches of others.

AGGLUTINATION.

The blood of normal (untreated pigs) may agglutinate virulent cultures of *B. cholerae suis* in dilutions as high as 1-250, usually less. The blood of young pigs contains less agglutinin as a rule than that of old pigs.

The blood of pigs having hog cholera as a result of virus inoculation may agglutinate *B. cholerae suis* in dilution as high as 1-800 but usually at a less dilution. Here again age is a factor in that old pigs develop more agglutinin than young ones. (Old pigs are likewise more resistant to hog cholera infection.)

The blood of pigs treated by the serum-simultaneous method may agglutinate *B. cholerae suis* in dilutions as high as 1-500.

The agglutination reaction seems to be one of immunity not of infection, at least, agglutinins develop in connection with immunity but perhaps not as a factor in the condition of immunity. This deduction is based upon the observation that a large percentage of pigs treated by the serum-simultaneous method show a low agglutinative power in the event of death, while of those that live 50 per cent. show the highest agglutinative power.

During the process of hyperimmunization, the agglutinin content of a pig's serum increases as a rule as the amount injected increases, and may fall during the tail bleedings unless more virus be injected.

If the agglutinogen in the virus is *B. cholerae suis* then the quantity of agglutinogen (number of *B. cholerae suis*) injected into a large serum hog during the whole process of hyperimmunization would ordinarily (if only freshly drawn virus is used) be less than would be contained in .10 cc. of a 24-hour bouillon culture of *B. cholerae suis.*

The injection of a number of *B. cholerae suis*, in bouillon culture, equal to that found in the total quantity of virus sufficient to hyperimmunize a large pig fails to stimulate the production of agglutinin to such an extent as is the case when the virus is injected.

Over one-third of the cases of serum hogs studied furnish a serum agglutinating at a dilution of 1-50,000.

The Dorset-Niles serum retains its agglutinative power for several days, almost unimpaired, when preserved in .5 per cent. carbolic acid, trikresol or formalin. The agglutinative power of a serum may diminish 50 per cent., more or less, after a period of 6 to 8 months.

The potency of the Dorset-Niles serum, the biological test being the standard, cannot be measured uniformly by its agglutinative power for *B. cholerae suis*. However, the biological test with pigs is a variable standard.

Sera of high agglutinative power, i. e., reacting at 1-2,000 or above, were potent in 85.71 per cent. of cases and not potent in 14.28 per cent.; sera of low agglutinative power, i. e., reacting at 1-1,000 or less, were potent in 45.45 per cent. of cases and not potent in 54.54 per cent.

The agglutinability of the different cultures used by us indicates that they belong to the same strain. They were isolated from the spleen

Note.—The maximum agglutination titer for pigs treated by the serum-simultaneous method is less than for pigs treated with virus only. This is because the former were all young pigs while the latter were mostly old. Comparing pigs of nearly equal size, those receiving 1 c. c. of virus only showed an average agglutinative power of 1-197, while those receiving 1 c. c. of virus and the Dorset-Niles serum showed an average agglutinative power of 1-262.

of virus pigs treated by virus having a common origin. We therefore believe that these cultures originated, in the original virus and not in an alleged normal habitat in the pig's intestine.

CONCLUSION.

We believe that the relation of *B. cholerae suis* to the porcine organism and to the filterable virus, and all the interrelation of these three factors in the production of a swine disease should be settled. A scientific understanding of hog cholera is impossible without this solution. The economic problems involved in the production of the Dorset-Niles serum or any other biological therapeutic agent for hog cholera, and the sanitary police control and eradication of this disease demand it.

The writer is not interested in a controversy over the merits of the different claims as to the etiologic significance of a non-cultivable, virus or a microscopic, cultivable virus for hog cholera. It is only wished that the matter may be placed beyond the stage of controversy.

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THE FERMENTING CAPACITY OF THE AVERAGE SINGLE CELL OF BACTERIUM LACTIS ACIDI.

Technical Bulletin No. 9.

BY OTTO RAHN.

INTRODUCTION.

Under "fermenting capacity of the average single cell" is understood the amount of products formed by an average cell of a certain species of microörganisms in one hour. This factor can be estimated in certain cases with a fair degree of accuracy, and it is the object of this paper to show how this can be done and how it is a valuable, perhaps even a necessary factor for the understanding of certain problems of fermentation. It will naturally be of no value to the manufacturer of fermentation products who considers microörganisms simply as the cheapest means of obtaining the desired products. But it may contribute to the understanding of fermentation processes, since it enables us to estimate the fermenting power of the individual cell, independent of its multiplication. The desire of microbiologists to know how much of a certain product is formed by one cell in a certain time is not unreasonable. Rubner,* in his studies concerning the energy requirements of bacteria, says: "It would seem to us inconceivable that anybody would study the consumption of foods or the formation of metabolic products by two species of animals without ascertaining how many individuals of each species are present and how much body weight they represent. If, therefore, metabolic experiments are supposed to have any real value, they must be connected with some kind of determination of the final crop of microörganisms."

If bacteriologists do not record the amount of living matter entering into reaction, it is simply because this seems impossible, on account of the minuteness of organisms and because of the continuous change

*Archiv f. Hygiene Bd. 48 (1904) p. 284.

in number. But it only *seems* impossible; by a mathematical calculation, the fermenting capacity of the average single cell can be computed.

The value of determining the fermenting capacity lies in the differentiation of the two main microbial activities: multiplication and fermentation. The amount of acid or alcohol or toxin formed by a culture is the result of many cells. We do not know the number that entered into reaction, and even the counting of bacteria would not add much to our knowledge since the number of cells is changing continuously from the time of inoculation. For practical work, the distinction between growth and fermentation per cell is not necessary, but for some questions of physiological significance it is necessary. For instance, it has never been demonstrated whether the optimum temperature for cell growth and the optimum temperature for fermentation are the same. This question may even be of some practical value. It can be decided only by determining the fermentation per cell, eliminating the multiplication. In order to determine whether toxins or any other compounds are direct or indirect products of metabolism, it remains to be determined whether or not there is a direct parallelism between growth and toxin formation. This can be done accurately by computing the fermenting capacity. If a certain substance stimulates fermentation, it is valuable to know whether this stimulation is due to an increased number of cells, to a faster fermentation of each individual cell, or to an increase in both fermenting and multiplying power. Many other similar problems could be mentioned where the fermenting capacity of the single cell would be very helpful.

The necessity of the distinction between fermentation and multiplication has already been mentioned and demonstrated by Duclaux (Traité de Microbiologie, Tome 4, 1901, p. 328).

"Imagine that we inoculate into equal portions of a medium equal quantities of different lactic bacteria, all other conditions being exactly alike. If we determine, by some means or other, the amount of acid produced in 24 or 48 hours, these results evidently would be taken as a measure of the "activity" of different lactics under the same conditions. It is well understood that the "activity" as defined above depends upon the given conditions, and that the organisms under study might range in different order, if one of these factors, e. g., the temperature, were changed. The activity, in the above sense, depends upon the amount of inoculation, and although this is no *specific* character, it must be known.

However, very seldom is it determined. Usually, the practice of comparison has been to introduce into the flasks not the same quantity of fully developed bacteria, but the same amount of inoculating material which has to multiply first before beginning to act, thus the result is a superposition of two factors which do not follow the same law: 1. The power of multiplication. 2. The fermenting activity of the organism. In order to measure the activity alone, the multiplication has to be nil or very insignificant. This can be accomplished, or nearly so, by inoculating with about as many cells as are found in the same volume of rapidly fermenting liquid."

"Activity" in the sense of Duclaux is the same as the suggested "fermenting capacity," only Duclaux uses as a basis the weight of bacteria, and the present paper suggests the single cell as being simpler and more easily determined.

The fermenting capacity of the single cell is really a measure of the amount of enzyme in the cell. The amount of alcohol produced by one cell under normal conditions indicates the amount of zymase present. If two lactic cultures differ in the amount of acid formed, this may be due either to a faster growth of one of the cultures, to a greater fermenting capacity, to both, or to a greater fermenting capacity though slower growth. The computation of the fermenting capacity decides between these various possibilities. If the fermenting capacity differs, this indicates a difference in the amount of zymase per cell. Since it is possible to measure the zymase in the cell, zymology might use this method to advantage. At present, in order to study these endoenzymes, it is necessary to prevent the multiplication of the enzyme-containing cells by chemical or physical means which usually affect the enzyme also. The method suggested in this paper separates multiplication and fermentation by means of a mathematical formula, without interfering at all with the natural development of the culture.

The fermenting capacity of the single cell is in certain ways related to the *virulence* of microörganisms which is fairly well defined in pathogenic bacteriology, but which is entirely vague if applied to dairy and soil bacteria.

It is customary to measure the rapidity of growth of microörganisms by the *rate of reproduction* which is the average time required by one cell to make two cells. This time is computed from the bacterial counts at the beginning and end of the experiment under the assumption that bacteria multiply in geometrical progression. This is not exactly, but nearly true. The rate of reproduction is not constant, of course, the multiplication being much faster in the beginning and ceasing entirely in old cultures. But under comparable conditions in young cultures, it is possible to obtain fairly well agreeing results representing a unit characteristic of the species under study. This unit may not represent the actual time it takes one cell to double, in fact, we know it does not, on account of our inaccurate methods of counting. It is, however, a valuable working unit, and its reliability is easily tested by the deviation in parallel experiments.

Nothing more can be expected from the computation of the fermenting capacity. It may not give the actual amount of products formed by one cell, and usually it will not, the error being due mostly to the inaccuracy of counting the cells and other irregularities. But it is, nevertheless, a working unit, the reliability of which can be proven experimentally.

II. THE FORMULA FOR THE COMPUTATION OF THE FERMENTING CAPACITY.

In this computation of the fermenting capacity it is assumed that bacteria multiply in geometrical progression, and that all young cells of a fresh, pure culture ferment alike. These two hypothetical conditions are discussed in a following subtitle.

We shall designate the number of bacteria in the beginning of the experiment as a; let t stand for the time in which the organisms are under consideration and in which the fermenting capacity of the cells is estimated, and b for the number of bacteria resulting from multipli-

cation in the period t. The bacteria are assumed to multiply in geometrical progression.

$$a \quad 2a \quad 2^2a \quad 2^3a \quad 2^4a \ldots\ldots\ldots\ldots 2^n a$$

The final number of bacteria, b, will then equal $2^n a$. From this equation, the number of generations, n, during the time of observation, t, is easily deducted mathematically:

$$2^n = \frac{b}{a}$$

$$n = \log^2 \frac{b}{a}, \text{ or, if changed to the common Briggs logarithms:}$$

$$n \log^{10} 2 = \log^{10} \frac{b}{a}$$

$$n = \frac{\log^{10} \frac{b}{a}}{\log^{10} 2}$$

Let the average rate of reproduction, i. e. the time required for the average cell to double, be y. This rate of reproduction, multiplied by the number of generations, must equal the total time of the experiment.

$$y\, n = t$$

$$y = \frac{t}{n}$$

or substituting the above value for n, we obtain

$$y = \frac{t \log 2}{\log\ b/a}$$

If we let x equal the amount of acid formed by one cell in one hour, a single cell will produce during one generation, i. e. during the time y, an amount of acid equal to xy. a cells will produce axy acid in one generation. Then they multiply, and $2a$ cells are forming acid, which will amount, during this second generation, to $2axy$. The division of cells takes place again, and now there are 2^2a cells which form altogether 2^2axy acid. The acid produced by the successive generations is therefore:

$$axy,\ 2axy,\ 2^2axy,\ 2^3axy$$

The final figure cannot be stated, unless arbitrarily.

The final number of cells is $2^n a$, but it cannot be stated when these bacteria have been formed and whether they have produced any acid and how much. The two extremes are the following: (1) The cells have been formed for some time, and are just ready to divide again, when the determination is made, in this case, the last acid formed would amount to $2^n axy$; (2) The bacteria just finished their last division when the final count was made, they have had no time to form

acid, therefore the last amount of acid formed would amount to $2^{n-1}axy$. There is no means of ascertaining the correctness of either probability. In fact, bacteria do not divide all at the same moment; this is assumed only for the convenience of computation. To determine the full values, the calculus is necessary.

It has been assumed above that the original number of bacteria a produces the total amount of acid axy before they multiply. Corresponding to this, it is also assumed in the further computation that the final number b has been formed just at the moment, the determination is made. These two assumptions will counterbalance one another to some extent. The final amount of acid is therefore $2^{n-1}axy$.

The total acid, S, which is determined by titration, is the sum of all these figures.

$$S = axy + 2axy + 2^2axy + \ldots\ldots + 2^{n-1}axy.$$
$$= axy\ (1 + 2 + 2^2 + 2^3 + \ldots\ldots + 2^{n-1})$$
$$= axy\ (2^n - 1)$$ according to the sum formula of geometrical progression.

$$S = xy\ (a2^n - a)$$
$$= xy\ (b - a)$$ by substitution of b for $a\ 2^n$.

We found above $y = \dfrac{t \log 2}{\log \frac{b}{a}}$

Substituting we obtain $= S\ \dfrac{xt\ (b - a) \log 2}{\log \frac{b}{a}}$

$$x = \frac{S \log \frac{b}{a}}{t\ (b - a) \log 2}$$

x is the amount of acid formed by the average cell in one hour, i. e. the fermenting capacity. S is the acid formed in the time t, a and b are the initial and final number of bacteria. In computing, care has to be taken to reduce both acid and bacterial numbers to the same unit of medium, either 1 cc. or 100 cc. or 1,000 cc.

After this manuscript had been finished, an attempt at computing the fermenting capacity of the single cell by Burchard was found in Archiv f. Hygiene Vol. 36, p. 283 (1899). Burchard, working with urea bacteria, considered the geometrical mean of the number of bacteria in the beginning and at the end of his experiments as the average of the acting cells. The geometrical mean gives the number of cells in the middle of the experiment, but this is not the average of all acting cells. By his method, he obtains figures which are much larger than those obtained by the above formula. It is easily proven, by Burchard's own data, that they are wrong. Burchard computes from his data that the fermenting capacity is 0.00,000,003 mg = 300×10^{-10} mg. urea per cell and hour; the rate of reproduction is 6.3 hours, the final number of bacteria is 42,-720,000 per cc., the amount of urea decomposed 1.78 mg. per cc. The urea decomposed by the last generation is 21,360,000 $\times$ 6.3 $\times$ 0.00,000,003

mg. = 4 mg., which contradicts the fact that only 1.78 mg. urea was found to have been decomposed. The new formula gives a fermenting capacity of 66×10^{-10} mg., only one fifth of that computed by Burchard, and the amount of urea fermented by the last generation is 0.885 mg. From this, it is evident that the preceding generations fermented 0.442 mg., 0.221 mg., 0.110 mg., 0.055 mg., 0.027 mg., etc. The sum of these first five data gives 1.74 mg. of urea.

Exactly the same formula with exactly the same errors has been applied later by Haake to the acid fermentation by *B. acidi lactici* Hueppe (Archiv f. Hygiene Bd. 42, p. 46). Besides the mistake in the formula, both these authors make an error in the arrangement of their experiments, letting the cultures develop for 72 hours at 37°C. Naturally, the bacteria are already dying and the maximum number is long passed when the bacteria are counted. This accounts for many rather strange conclusions, especially for the statement that the slower the fermentation, the faster the division of cells. The basis of these conclusions which can be found in several text books is not sound enough to uphold these views, and a revision will be necessary.

III. DISCUSSION OF THE ASSUMPTIONS IN THE PREVIOUS CHAPTER.

In the computation of the above formula, three assumptions have been made which may not be accepted by all bacteriologists. These assumptions are: (1) That bacteria multiply in geometrical progression; (2) that bacteria cause fermentation as soon as they are transferred into a fresh medium; (3) that the cell as counted by the plate method in young cultures is the most advantageous unit. These assumptions require a justification.

The Multiplication of Bacteria in Geometrical Progression has been given considerable attention. It has been found that this process is not wholly reliable for there are too many possible deterrent factors. A number of investigators* have found that immediately after being transferred, bacteria grow very slowly, but after a few hours, reach a normal rate of multiplication which remains nearly constant for a certain period. This initial retardation is too insignificant to have any appreciable influence upon the computation of the fermenting power, since it takes place at a time when the number of cells is too small to form measurable quantities of fermentation products.

Later Barber† demonstrated by direct microscopic counts of *Bacillus coli*, that actually there is no such retardation. The findings of the other authors are probably due to an error caused by the plate method. Since, however, all data in this paper are obtained by this method, it is shown in the following pages that this apparent retardation is of no avail.

*Basenau, Archiv. f. Hygiene Bd. 23 (1895) p. 44.
Müller, Zeitschr. f. Hygiene, Bd. 20 (1895) p. 245.
Kossowicz, Zeitschr. f. d. landw. Versuchswesen Oesterreichs Bd. 6 (1903) p. 275.
Rahn, Centralbl. f. Bakt. II, Bd. 16 (1906) p. 417.
†Journal of Infectious Diseases Vol. 5 (1908) p. 379.

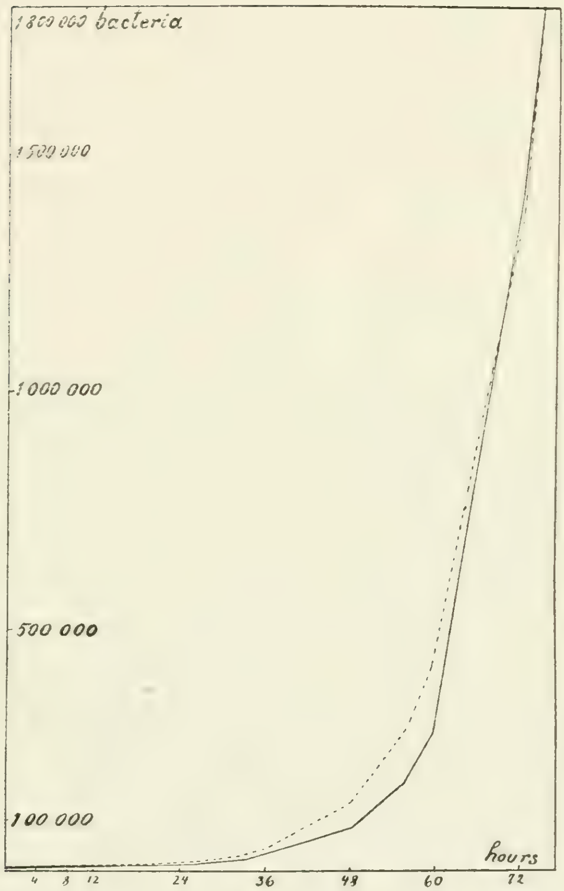

FIG. 1.
Theoretical and Actual Growth of Bacterium A.
Dotted line............theoretical number.
Full line________actual number.

The following table after Müller gives the actual numbers of a certain bacterium in broth counted at different times. The last column gives the numbers after inoculation by the plate method computed under the supposition that the multiplication had followed the geometrical progression.

TABLE I.—*Actual and Theoretical Increase of Bacterium A at +6° after Muller.*

Time.	Number of cells found.	Number of cells computed.
0 hours	1,370	1,370
4 hours	1,650	2,010
8 hours	2,160	2,940
12 hours	2,860	4,310
24 hours	8,000	13,530
28 hours	11,600	19,820
32 hours	17,500	29,000
36 hours	27,900	42,500
48 hours	79,900	133,700
52 hours	130,000	196,000
56 hours	180,000	287,000
60 hours	273,000	542,000
72 hours	1,353,000	1,320,000
76 hours	1,956,000	1,956,000

The retardation of growth is evident, as is also shown in the curves of Fig. I. But this retardation of growth comes at a time when the number of cells is very small. The products formed at this early period of growth are so insignificant in quantity that we cannot detect them by any chemical means. This is easily shown by the following Table II, giving the growth and acid formation of *Bact. lactis acidi* in milk. The rate of reproduction, i. e. the number of minutes required for one cell to double, is lowest, or the multiplication is fastest when the first traces of acid can be detected chemically. Soon after this point has been reached, the rapidity of growth decreases, slowly at first, then quite rapidly after about 0.3% of acid has been formed. At 0.4% to 0.5% of acid, growth ceases entirely. The table shows that the rate of growth is not constant, and that the retardation of growth in a young culture is overcome by the time the products can be analyzed. Therefore, the fermenting capacity will not be influenced seriously by the initial retardation. As long as the gradual decrease of the rapidity of growth is not considered in the mathematical equation, the results will be the more accurate the shorter the period of experiment.

TABLE II—*Growth and Fermentation of Bacterium lactis acidi.*

Time.	Cells per cc.	Acid per cent.	Rate of growth minutes.	Cells per cc.	Acid per cent.	Rate of growth minutes.
0 hours	38,000	0	....	38	0	....
3 hours	200,000	0	74.8	183	0	79.0
6 hours	1,710,000	0	58.1	1,750	0	55.0
9 hours	19,600,000	0.007	50.8	23,250	0	52.7
12 hours	113,000,000	0.018	70.9	301,000	0	48.5
15 hours	435,000,000	0.086	92.2	4,800,000	0.005	45.1
18 hours	1,135,000,000	0.263	130.0	43,200,000	0.011	56.8
21 hours	1,370,000,000	0.434	663.0	177,000,000	0.027	88.5
24 hours	1,550,000,000	0.479	1010.0	685,000,000	0.132	92.2
27 hours	1,350,000,000	0.502	....	1,240,000,000	0.338	210.3
30 hours	1,300,000,000	0.524	....	1,520,000 000	0.489	619.8
33 hours	1,440,000,000	0.520	....	1,390,000,000	0.527	....
36 hours	1,610,000,000	0,538	....	1,750,000,000	0.531	....

Fermentation in Very Young Cultures.—The second point requiring an explanation is the assumption that bacteria cause fermentation as soon as they are transferred into a suitable medium. This assumption contradicts the opinion of many bacteriologists who believe that bacteria do not begin to ferment until a certain period of growth has been reached. It seems a rather general belief that microörganisms in the earliest stage of growth do nothing but multiply and after they have reached a certain number, fermentation starts in and multiplication becomes slower. When and where this idea originated can not be ascertained, but the general opinion is inclined to separate the two processes as independent. Two quotations will suffice as examples: Knösel (Centralbl. f. Bakt. II, Bd. 8, p. 272) speaking of multiplication and fermentation of yeasts, says: "Both these life functions run parallel; as a rule, however, especially with a small inoculation of yeast, the sugar-destroying action is preceded by a short multiplication. After this has taken place, fermentation begins."

H. W. Conn (Bacteria in Milk and Its Products, 1903, p. 74) states: "Now, while there is a general parallelism between the growth of these organisms and the production of lactic acid, the parallel is by no means a close one. For a considerable time after milk is inoculated with lactic bacteria, there is no increase in the amount of lactic acid, although the bacteria are themselves multiplying rapidly and becoming very numerous. Then there is a rapid increase in the development of lactic acid, accompanying a still further growth in the bacteria."

These quotations are just chosen to illustrate the general opinion of bacteriologists. No data are on record to prove the above statement that in the earlier stages of growth, multiplication goes on without or with but little fermentation. In fact, no data can exist because it is impossible to prove either contention. It requires but a very simple computation, to show the impossibility of any proof. Sour milk with about 1% of lactic acid contains at least 1,000,000,000 bacteria per cc. If it takes 1,000,000,000 bacteria per cc. to make 1% of lactic acid, 1,000,000 bacteria would make 0.001% of acid in the same time, which is much less than can be determined analytically. It would also take 1,000,000 bacteria one thousand times as long to make 1% of lactic acid.

This is the point that is commonly overlooked. A few thousand bacteria are inoculated into milk, they multiply rapidly, after a few hours, there are several million cells per cc., and yet no acid; the conclusion is that they did not form any acid in this period. This deduction is wrong. A calculation will show that if they form acid at the ordinary rate, the amount cannot possibly be detected by the usual chemical methods. This explains also the fact that the discrepancy between growth and fermentation is observed especially with small inocula. With large inocula, the products appear soon after, and the "parallelism" is proved.

The definition "Period of incubation is the time during which bacterial proliferation is taking place without a corresponding increase in acidity" is not based on actual data. From the time the products are formed in quantities sufficient to be analyzed the parallelism is doubtless established. Why should a discontinuation of the parallelism be supposed as long as there are no indications of it, no present means of establishing it, and no pertinent analogies even to make it appear

probable? Nothing contradicts the statement that the period of most rapid growth and of the most rapid fermentation coincide although it is beyond actual demonstration at a time when the products are not chemically determinable. This statement becomes logically necessary if we consider fermentation as the source of energy for the life functions of the microbial cell. The period of incubation should be defined as the period during which the fermentation products are within the limits of analytical error.

The single cell as unit.—A brief explanation should be given why the single cell is chosen as unit instead of the weight of the acting cells. Both these standards have their disadvantages. Rubner[1] has demonstrated that there is a large difference between different cells; he has also pointed out that many yeast cells may still ferment, but not develop on plates, the plate method being practically the only one coming into consideration in this paper.[2] In spite of the great difficulties in determining the weight of bacteria in a culture, Rubner in his experiments on metabolism of bacteria preferred it to the counting of cells. The reasons which caused Rubner to weigh the bacteria have little bearing in this work. Since only young cultures are considered, the plate method is exact enough for counting and probably more exact then Rubner's method which could not be applied to milk cultures. The difference between the individual cells cannot be denied but the variation in a well-bred culture is very small and on the other hand, the weight is not a very reliable unit inasmuch as cells may or may not contain considerable amounts of glycogen, fat, etc. Therefore, for the purposes of this paper the counting of bacteria seems fully as, or more desirable than the weighing method.

As to Duclaux, he probably did not think of the possibility of computing the fermenting power per cell. His method was quite different. He added so many bacteria to the culture that there would probably be no increase of cells, consequently he had a constant weight of bacterial mass acting upon the sugar. This method, though it served his purpose, is less accurate and can be applied only in a few instances, where bacteria can be filtered out quantitatively.

Method of Counting.—The common method of counting bacteria by plating is doubtless not an accurate determination of the number of single cells. Very commonly, especially with *Bacterium lactis acidi*, two cells will remain attached for some time after the fission has taken place as may be easily demonstrated by the microscope and will thus give but one colony on the plate. Besides, old cells are apt to lose their vitality and may not be able to multiply in agar or gelatin though they still may cause fermentation. In order to determine the relation between the actual microscope and the plate method, comparative counts were made in litmus lactose agar and by the direct method of MacNeal,[3] Latzer and Kerr. The latter consists in spreading the content of a standard loop between two cover-glasses, staining and counting a number of microscopic fields. Two different strains of lactic bacteria were used for these experiments.

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[1]Rubner, Archiv. f. Hygiene, Bd. 48, p. 260 and Bd. 49, p. 355.
[2]About microscopic counts see next paragraph.
[3]Journal of Infectious Diseases, vol. 6 (1909) p. 146.

The first series was made in milk which was neutralized every 24 hours in order to obtain old cultures with plenty of cells. The Gram stain was used since other methods stained the milk proteins also. The averages of the duplicate counts are given in the following table:

	Acidity.	Plate count.	Microscopic count.
Culture, 24 hours old	76°	....	5,000,000,000
24 hours after first neutralization	84°	1,280,000,000	2,256,000,000
48 hours after second neutralization	92°	1,660,000,000	1,278,000,000

A duplicate experiment with another strain gave the following data:

	Acidity.	Plate count.	Microscopic count.
Fresh culture, 48 hours old	64°	....	2,130,000,000
24 hours after first neutralization	46°	1,620,000,000	852,000,000
48 hours after second neutralization	52°	1,200,000,000	1,278,000 000

The microscopic counts are doubtless very unsatisfactory, since they show a decrease in the total number which is impossible. The discrepancy was largely due to the difference in the consistency of the sour milks, the same loop holding different quantities of milk with different samples. In the following set of counts 20 loops of sour milk were weighed and averaged with each determination.

	Acidity.	Plate count.	Microscopic count.
July 4, 24 hours culture	58°	650,000,000	2,590,000,000
July 5, 24 hours after first neutralizing	66°	1,000,000,000	780,000,000
July 6, 24 hours after second neutralizing	58°	1,480,000,000	1,909,000,000
July 7, 24 hours after third neutralizing	46°	2,450,000,000	1,985,000,000

The average weights per loop on these 4 days were 1.39 mg, 2.0 mg, 2.32 mg, 2.00 mg. If the averages vary so much, it is very plain that these figures may not represent at all the accurate weight of a single loop.

The experiment was repeated with the only difference that this time the loops of milk for counting were removed after neutralization, to avoid the curd which could not be broken up satisfactorily by shaking.

	Acidity.	Plate count.	Microscopic count.
July 11, 24 hours culture	42°	780,000,000	2,250,000,000
July 12, 24 hours after first neutralization	48°	1,250,000,000	2,380,000,000
July 13, 24 hours after second neutralization	38°	1,410,000,000	1,980,000,000

The weights per loop agreed much better in this case, the average data being 1.60, 1.93 and 1.81 mg. The counts, also, were more satisfactory, but do not agree at all with the increasing plate counts.

As a last test, a three-days'-old milk culture of *Bacterium lactis acidi* was counted microscopically on five sets of cover-glasses to determine the probable error of microscopic counts of milk cultures. The milk was neutralized before being weighed out. Duplicate determinations gave the milk per loop 1.83 and 1.89 mg. The microscopic counts gave the following data:

1,960,000,000
2,240,000,000
2,360,000,000
2,400,000,000
2,520,000,000

The greatest error is approximately 28%.

The results are altogether unsatisfactory, and the data are not consistent enough to warrant a substitution of this method for the plate method. The reason is probably to be sought in the general inaccuracy of the loop as measure, together with the impossibility of obtaining comparable data from curded milk. Considering also that young cultures cannot be counted at all by the microscopic method on account of too small numbers, all counts were continued by the plate method.

IV. FERMENTING CAPACITY OF VARIOUS STRAINS OF BACTERIUM LACTIS ACIDI.

The formula for the fermenting power, according to subtitle II, is

$$x = \frac{S \log \frac{b}{a}}{t\,(b-a) \log 2}$$

It shows that four data are needed for the computation: $S =$ the total amount of products formed, $t =$ the time of experiment, and the initial and final number of bacteria a and b. Though these data are easily determined, there are only very few experiments to be found in the current literature that give all of these four data. In fact, as far as the lactic bacteria are concerned, the author succeeded in finding only one series of experiments complete enough to allow the computation of the fermenting power. Marshall and Farrand* in their experiments on the association of the lactic organisms give a large number of data with pure cultures of *Bacterium lactis acidi* which are compiled in Table III.

*Marshall and Farrand, Special Bul. 42, Mich. Agric. College, 1908.

TABLE III—*Fermenting Capacity of four Different Strains, after Marshall and Farrand.*

Strain.	Expt.	Initial number per cc.	Final number per cc.	Acidity increase.	Time in hours.	Fermenting capacity.	
						Individual.	Average.
1	a	0.06*	1,000,000,000	15°	53	8.6×10^{-10}	17.6×10^{-10}
	b	0.09*	2,900,000,000	67°	65	11.2×10^{-10}	
	c	0.02*	243,000,000	27°	114	28.9×10^{-10}	
	d	1340	117,000,000	9°	73	15.6×10^{-10}	
	e	0.14*	111,000,000	9°	72	30.0×10^{-10}	
	f	7.65	453,000,000	28°	101	14.0×10^{-10}	
	g	481	372,000,000	10°	67	15.0×10^{-10}	
2	a	20	1,990,000,000	49°	93	6.3×10^{-10}	7.4×10^{-10}
	b	1270	4,180,000,000	58°	72	3.8×10^{-10}	
	c	2750	2,300,000,000	40°	48	6.4×10^{-10}	
	d	18	1,970,000,000	60°	91	8.0×10^{-10}	
	e	2850	1,210,000,000	10°	42	3.3×10^{-10}	
	g	18	1,440,000,000	62°	66	15.8×10^{-10}	
	i	16	1,900,000,000	59°	67	11.2×10^{-10}	
	j	173	1,600,000,000	37°	48	10.0×10^{-10}	
	k	480	5,850,000,000	55°	44	4.5×10^{-10}	
	m	2960	2,920,000,000	35°	44	4.9×10^{-10}	
3	a	22.4	194,000,000	5°	54	9.9×10^{-10}	13.2×10^{-10}
	c	20.3	116,000,000	47°	45.5	160.8×10^{-10}	
	e	24.1	2,410,000,000	42°	47	8.9×10^{-10}	
	f	0.18*	1,100,000,000	54°	53	27.1×10^{-10}	
	g	23.5	1,500,000,000	26°	47.5	8.5×10^{-10}	
	h	38	1,700,000,000	37°	54	10.4×10^{-10}	
	i	30.7	1,070,000,000	40°	48	17.6×10^{-10}	
	k	23	2,280,000,000	39°	40	10.2×10^{-10}	
4	b	0.23*	1,460,000,000	36°	55	13.1×10^{-10}	19.6×10^{-10}
	e	3.75	114,000,000	31°	49	124.2×10^{-10}	
	f	4.5	26,000,000	10°	49.5	157.1×10^{-10}	
	g	23	1,000,000,000	52°	47	25.3×10^{-10}	
	h	3.38	604,000,000	28°	56	20.4×10^{-10}	
	i	15.6	1,000,000,000	42°	43	22.8×10^{-10}	
	o	34.9	1,830,000,000	46°	42	13.8×10^{-10}	
	g	12.6	1,750,000,000	77°	48	22.3×10^{-10}	

*These numbers mean that 6, 9, 2, etc., cells respectively had been transferred into 100 cc. of milk.

The table has four sections each of which represents a different strain of *Bacterium lactis acidi.* The average fermenting capacity from all data is 14×10^{-10}, i. e. $\frac{14}{10,000,000}$ of one milligram of lactic acid have been produced by the average cell in one hour. This amount seems ridiculously small, but it is really an enormous amount compared with the weight of the cell. MacNeal, Latzer and Kerr* found that 1 g. of dried coli bacteria contained from 46 to 57×10^{-11} cells, or in other words, the dry matter of one cell weighs approximately $\frac{1}{50} \times 10^{-11}$ g or 2×10^{-10} mg. Bacteria having approximately 80 to 90% moisture, the actual weight of a living cell of *B. coli* is between 10 and 20×10^{-10} mg. *Bacterium lactis acidi* is smaller than *B. coli.* The comparison of the data shows that each cell forms about its own weight of lactic acid in one hour.

Considering each strain by itself, a great discrepancy of results is quite evident. Three figures, namely 3c, 4e and 4f, are ten times as

*Journal Infectious Diseases Vol. 6 (1909) p. 148.

high as the average, and are therefore not considered. An error must have crept in somewhere, as the comparison of all data shows; probably the final number of cells is recorded one decimal place too low. Excluding these three data, the variations are,

with Strain 1 from 8.6 to 30.0, average 17.6.
with Strain 2 from 3.3 to 15.8, average 7.4.
with Strain 3 from 8.9 to 27.1, average 13.2.
with Strain 4 from 13.1 to 25.3, average 19.6.

The variation is quite large with Strain 2, the maximum is 5 times as large as the minimum. The averages show that Strain 2 was quite different from the other three lactic types.

Another experiment showing a very wide variation in parallel experiments is that given in Table IV. This experiment was made with a dairy starter, carried on in pasteurized milk, and apparently a pure culture, as far as could be judged from the gelatin plates. Dilutions in decimal order were transferred into flasks with 100 cc. of sterile milk. The acidities and numbers of bacteria were determined after 12 and 24 hours' growth at 21°. The highest fermenting capacity is more than three times as great as the lowest.

Smaller variations were obtained with Strain II which has been used in the majority of the following experiments. This strain has been transplanted in the laboratory for about two years at least every second day from milk to milk. It is a rapid acid producer and is used as starter in several creameries. In Table V are compiled all data obtained with 24-hour cultures of this strain. Some of the experiments have been carried on more than a year apart, and the only identical factors are the well-bred culture and the temperature of about 21-24°C. The very last experiment shows both the highest and the lowest fermenting capacity, 13.7 and 33.8×10^{-10} mg. The next extremes are 16.6 and 30.5. The proportion of lowest to highest number is 1:2.5 and 1:1.6 respectively, while in the experiments of Marshall and Farrand, with freshly isolated cultures, the corresponding proportions of the four strains were 1:3.5, 1:4.8, 1:3.9 and 1:1.9. Table IV with the dairy starter gives the proportion of the two extremes 1:3.3. This shows that the greatest variation of the well-bred Strain II is smaller than that of freshly isolated pure cultures.

TABLE IV.—*Fermentation of Milk by a Dairy Starter.*

	Fresh.		After 12 hours.					After 24 hours.				
	Bacteria in 1 cc.	Acidity.	Number in 1 cc.	Acidity.		Acid in 1 cc.	Fermenting capacity.	Bacteria in 1 cc.	Acidity.		Acid in 1 cc.	Fermenting capacity.
				Total.	Increase.				Total.	Increase.		
1	4,320,000	17.5°	313,000,000 318,000,000	44°	27.0°	2.160 mg.	40.5×10^{-10}	....	....	....	....	....
2	432,000	16.5°	153,000,000 170,000,000	25°	8.5°	0.765 mg.	33.3×10^{-10}	648,000,000 660,000,000	81.0°	56.0°	5.040 mg.	15.3×10^{-10}
3	43,200	16.5°	49,000,000 69,000,000	19°	2.5°	0.225 mg.	33.2×10^{-10}	534,000,000 568,000,000	72.5°	53.5°	4.815 mg.	32.2×10^{-10}
4	4,320	16.5°	....	....	....	....	....	231,000,000 278,000,000	38.0°	21.5°	1.935 mg.	50.3×10^{-10}
5	432	16.5°	....	....	....	....	....	170,000,000 190,000,000	25.0°	8.5°	0.765 mg.	33.1×10^{-10}
6	43	16.5°	....	....	....	....	....	105,000,000	19.5°	3.0°	0.270 mg.	22.6×10^{-10}

TABLE V.—*Fermenting Capacity of Strain II.*

Table.	Time hours.	Bacteria per cc.		Acidity.		Fermenting capacity.
		Beginning.	Final.	Beginning.	Final.	
XIV A	24	13,100	1,575,000,000	17.0°	79.25°	25.0×10^{-10}
B	24	157,000	1,500,000,000	17.0°	78.25°	20.2×10^{-10}
	24	1,570	1,230,000,000	17.0°	69.00°	30.5×10^{-10}
XV	24	600	1,150,000,000	19.5°	51.50°	21.8×10^{-10}
XXa B	24	193,000	1,400,000,000	17.0°	75.75°	20.1×10^{-10}
	24	1,930	1,345,000,000	17.0°	64.75°	25.2×10^{-10}
C	24	183,000	1,500,000,000	17.0°	73.50°	18.6×10^{-10}
	24	1,830	1,385,000,000	17.0°	70.50°	28.3×10^{-10}
D	24	132,000	1,590,000,000	17.0°	72.00°	18.0×10^{-10}
	24	1,320	1,065,000,000	17.0°	43.00°	18.4×10^{-10}
E	24	134,000	1,685,000,000	13.0°	66.50°	16.6×10^{-10}
	24	1,340	1,665,000,000	13.0°	52.75°	18.1×10^{-10}
F	24	186,000	1,935,000,000	13.0°	66.00°	13.7×10^{-10}
	24	1,860	1,040,000,000	13.0°	62.00°	33.8×10^{-10}

It is readily seen that here, as in all biological experiments the individuality is quite apt to cause wide variations; it is also plain that the variation can be reduced materially by experimenting with an organism that has been selected and cultivated under the same conditions so as to impress and standardize the characters under study.

There is a variation of the microörganisms in each strain; there is also a decided difference between the various strains studied. Compiling all the data available in this paper from lactic bacteria in milk at 21°C., we obtain the following table:

TABLE VI—*Average Fermenting Capacity of Various Strains.*

Investigator.	Name of strain.	Table.	Number of single determinations.	Average fermenting capacity.
Marshall and Farrand	1	II	7	17.6×10^{-10}
Marshall and Farrand	2	II	10	7.4×10^{-10}
Marshall and Farrand	3	II	7	13.2×10^{-10}
Marshall and Farrand	4	II	6	19.6×10^{-10}
Rahn and Iwazumi*	....	*	2	16.5×10^{-10}
Rahn	a	IV	8	32.5×10^{-10}
Rahn	II	V	14	22.0×10^{-10}
Rahn	IV	XVI XVII	3	13.3×10^{-10}

Average of 57 determinations 17.8×10^{-10}.

*Not furnished in this paper.

V. THE INFLUENCE OF AGE.

In the introduction, it has been stated that the fermenting capacity is not a constant quality of the cell, but it changes like the rate of multiplication, and though it probably varies but little in the early stage of growth, it decreases rapidly as the fermentation products accumulate. In order to obtain comparable results, it is therefore necessary to use young cultures. The comparison would be absolutely correct only, if all experiments were carried on until an arbitrary standard concentration of fermentation products has been reached. This is not always possible, however, since too much work is required in watching the cultures so closely.

Variation of the Fermenting Capacity during the Entire Development of a Culture. The formation of acid in cultures of *Bacterium lactis acidi* is soon checked by an accumulation of products which interfere with further fermentation. The retardation of the acid formation naturally causes a decrease of the fermenting capacity. This is plainly demonstrated in the following experiment where acidity and bacterial numbers of a pure culture of Strain II were determined every three hours for 36 hours. The two series differ only in the amount of inoculation, culture A having 1,000 times as many cells at the start as culture B. For 6 and 12 hours respectively no increase in acidity is noticeable. The first increase is very small and cannot be determined accurately; hence the deviation in the fermenting capacity. After that, the fermenting capacity is fairly constant until an acidity of 50-60° has been reached. From then on, the decrease is very rapid. Multiplication ceases earlier than fermentation. (See table on next page.)

This experiment was carried on for the purpose of demonstrating that there is no evidence of an early stage of growth without fermentation. From the time the first traces of acid can be determined, the data show that the younger the culture, the faster is the fermentation caused by each single cell. What happened before the acid could be determined, we have no means of telling. It can be easily calculated, however, that if the cells formed acid during this period at the normal rate, the amount would be within the limits of analytical error.

Similar results are found in several of the later experiments, and there is not a single exception to this rule. A few of the data are compiled in the following table:

Fermenting Capacity in Different Stages of Development.

Strain.	Table.	0-12 hours.	12-24 hours.	Over 24 hours.
II	XV	17.9×10^{10} mg.	7.6×10^{-10} mg.	....
II	XV	....	21.8×10^{-10} mg.	1.4×10^{-10} mg.
IV	XVI	10.5×10^{-10} mg.	1.0×10^{-10} mg.	0.6×10^{-10} mg.
IV	XVI	19.9×10^{-10} mg.	1.6×10^{-10} mg.	0.8×10^{-10} mg.
IV	XVII	19.0×10^{-10} mg.	1.6×10^{-10} mg.	1.0×10^{-10} mg.

For further data see also tables XXI, XXII, XXIII, XXIV.

The difference in the fermenting capacity of young and old cultures will be evident also in cultures of the same age, but with different amounts of inoculum. A good many experiments in this paper have been carried on in duplicates with different amounts of inoculum, and the result is that in all cases the lowest inoculum showed the highest fermenting capacity, being actually the younger culture. This is especially plainly seen in Table V.

Effect of Neutralization.—To obtain old cells unchecked by their own products, full-grown milk cultures were neutralized with sterile normal alkali to the normal acidity of milk. A milk culture of Strain II, 36 hours old, 80° acid, was neutralized to 11°. The bacteria were counted immediately before and one-half hour after neutralization, and then after 4 and 8 hours. The experiment was carried on in duplicate.

TABLE VII.—*Growth and Acid Production of Strain II.*

Hours.	A. Number per cc.	A. Acidity.	A. Rate of reproduction, (minutes).	A. Fermenting capacity per hour.	B. Number per cc.	B. Acidity.	B. Rate of reproduction.	B. Fermenting capacity, per hour.
Beginning..	38,000	16.5° 16.5°	....	....	38	16.5° 16.5°	....	....
3 hours	184,000 216,000	16.5°	74.8	....	160 205	16.5°	79.0	....
6 hours	1,600,000 1,820,000	16.5° 17.5°	58.1	....	1,720 1,780	16.5°	55.0	....
9 hours	18,700,000 20,500,000	17.0° 17.5°	50.8	46.2x10^{-10}	21,700 24,800	16.5° 16.5°	52.7	....
12 hours	112,000,000 114,000,000	18.5° 18.5°	70.9	10.0x10^{-10}	300,000 302,000	16.5°	48.5	....
15 hours	430,000,000 440,000,000	26.0° 26.0°	92.2	13.8x10^{-10}	4,700,000 4,900,000	17.0° 17.0°	45.1	(148.0x10^{-10})
18 hours	1,000,000,000 1,270,000,000	45.5° 46.0°	130.1	11.7x10^{-10}	43,000,000 43,400,000	17.5° 18.0°	56.8	16.5x10^{-10}
21 hours	1,250,000,000 1,490,000,000	63.5° 66.0°	663.0	6.6x10^{-10}	172,000,000 181,000,000	19.5° 19.5°	88.5	8.1x10^{-10}
24 hours	1,490,000,000 1,610,000,000	69.5° 70.0°	1010.0	2.0x10^{-10}	650,000,000 720,000,000	32.0° 32.5°	92.2	13.5x10^{-10}
27 hours	1,300,000,000 1,390,000,000	71.5° 73.0°		0.5x10^{-10}	1,230,000,000 1,240,000,000	53.5° 54.5°	210.3	10.6x10^{-10}
30 hours	1,170,000,000 1,420,000,000	73.5° 76.0°	....	0.5x10^{-10}	1,470,000,000 1,560,000,000	70.0° 71.5°	619.8	5.2x10^{-10}
33 hours	1,380,000,000 1,500,000,000	73.0° 75.5°		0	1,280,000,000 1,500,000,000	74.5° 75.5°	....	0.9x10^{-10}
36 hours	1,550,000,000 1,660,000,000	77.0° 75.5°	......	0	1,670,000,000 1,830,000,000	75.0° 76.0°	....	0

TABLE VIII.—*Development of Strain II After Neutralization.*

Time.	A.			B.		
	Number per cc.	Acidity.	Fermenting capacity.	Number per cc.	Acidity.	Fermenting capacity.
Beginning	1,690,000,000 1,860,000,000	10.5° 11.0°	....	1,160,000,000 1,220,000,000	12.0° 12.5°	....
2 hours	....	36.0° 36.5°	....	....	33.5° 33.5°	....
4 hours	3,050,000,000 3,330,000,000	58.5° 58.5°	6.43	2,830,000,000 3,120,000,000	54.0° 53.5°	6.91
6 hours	....	65.5° 66.5	....	....	63.5° 64.0°	....
8 hours	3,220,000,000 3,270,000,000	67.5° 68.5°	0.66	3,250,000,000 3,320,000,000	68.0° 70.5°	1.08
24 hours	....	69.0° 70.0°	....	....	69.0° 69.0°	....

The counts show no great difference before and after neutralization. The actual figures are

	A.	B.
before	1,570,000,000 1,730,000,000	790,000,000 950,000,000
after	1,690,000,000 1,860,000,000	1,160,000,000 1,220,000,000

The fermenting capacity in the first four hours is a little, but not much, lower than in the preceding experiment carried on with the same strain.

The bacteria multiplied again after neutralization, approximately doubling their number. The final acidity is lower than that of the fresh culture. It may be mentioned that the milk was not curdled after 8 hours, though enough acid was formed to curdle normal milk; curd was formed after 24 hours.

The fact that the bacteria fermented and multiplied again after neutralization of the soured milk made it seem worth while to try the effect of repeated neutralization. The following two tables give duplicate experiments with two different strains of lactic bacteria, Strain II and Strain IV. For these data I am obliged to Mr. L. R. Himmelberger.

There is a great difference in the effect of neutralization upon these two strains of lactic bacteria. Bacterium II increases decidedly after the first neutralization ,and reaches its maximum number after the third neutralization. The number is then constant until a total of about 340° of acid has been formed. After that, the number drops rapidly, and at the same time the acidity increases very slowly. The cells probably by this time are injured so much by the exposure to sodium lactate that they die. The total amount of acid produced is 366° and 357° respectively.

Strain IV is, under normal conditions, a very slow acid producer; at 20°C, to 25°C., it requires 36-48 hours to curdle milk, while Strain II does it in 20 hours. Bacterium IV is much more sensitive to its own products; after the first neutralization, the number of bacteria does not increase, though fermentation takes place. The number remains fairly constant until about 160°-180° of acid have been produced; then, the number drops rapidly and the amount of acid formed from then on is very insignificant. The total acid formed is 202° and 176° respectively. It is not certain with either of the two strains that the discontinuation of life processes in these cultures is entirely due to the accumulation of sodium lactate. Possibly, other products are form-

TABLE IX.—*Development of Strain II in Milk Repeatedly Neutralized. Series 1.*

Acidity after each neutralization.	Time in hours.	Acidity after fermentation.	Increase of acid.	Number of bacteria.	Fermenting capacity.
16° (Fresh)	......	77.0° 78.0°	61.5°	500,000,000 780,000,000	?
14.5° 15.0°	24	77.5° 76.0°	61.0°	2,130,000,000 2,340,000,000	2.0×10^{-10}
20.0° 20.0°	24	72.0° 73.0°	52.5°	2,210,000,000 2,490.000,000	0.9×10^{-10}
19.0° 20.0°	24	64.0° 65.0°	45.0°	2,850.000,000 2,900,000,000	0.6×10^{-10}
Continued (64.5°)	19	71.0° 72.0°	7.0°	1,960,000,000 2,100,000,000	....
20.0° 20.5°	48	63.0° 64.0°	43.0°	2,030,000,000 2,120,000,000	0.4×10^{-10}
Continued (63.5°)	24	70.5° 72.0°	8.0°	2,130,000,000 2,260,000,000	....
24.0° 25.0°	19	46.0° 47.0°	22.0°	2,510,000,000 2,660,000,000	0.5×10^{-10}
Continued (46.5°)	24	50.0° 52.0°	4.5°	2,200,000,000 2,320,000,000	....
7.5° 8.0°	24	48.0° 48.5°	40.5°	2,100,000,000 2,410,000,000	0.7×10^{-10}
Continued (48.3°)	24	50.0° 51.0°	2.0°	....	....
27.0° 28.0°	48	42.0° 43.0°	15.0°	1,580,000,000 1,730,000,000	0.2×10^{-10}
30.0° 31.0°	24	32.5° 34.0°	3.0°	870,000,000 890,000,000	....

ed and finally interfere with the normal functions of the cell. The existence of such compounds has been shown by Zae Northrup* in the effect of different lactic bacteria upon the typhoid bacillus.

The fermenting capacity of all these cultures is quite low. Even after the first neutralization, the fermenting capacity of Strain II is not equal to the one in the preceding experiment (6.4 and 6.9 x 10^{-10} mg). This is however, due to the incomparable data. In the former experiment, the time of observation is four hours, and in these first hours, the increase of acidity is most rapid. If the data of Table VIII are figured for 24 hours, the average fermenting capacity is approximately 0.9x10^{-10} mg. The fermenting capacity drops quite noticeably after the second

Series 2.

Acidity after each neutralization.	Time in hours.	Acidity after fermentation.	Increase of acid.	Number of bacteria.	Fermenting capacity.
16.0° (fresh)	....	77.0° 77.5	61.0°	690,000,000 820,000,000	....
14.0° 14.5°	24	75.0° 76.0°	61.0°	1,940,000,000 2,090,000,000	3.3x10^{-10}
19.0° 20.0°	24	70.0° 70.0°	49.5°	2,280,000,000 2,350,000,000	0.9x10^{-10}
21.5° 22.0°	24	63.5° 64.5°	42.0°	2,910,000,000 3,040,000,000	0.8x10^{-10}
Continued (64.0°)	19	70.0° 70.5°	6.0°	2,060,000,000 2,190,000,000	....
19.5° 20.0°	48	62.0° 62.5°	42.5°	2,100,000,000 2,250,000,000	0.5x10^{-10}
Continued (62.3°)	24	70.0° 72.0°	9.0°	2,060,000,000 2,130,000,000	....
21.0° 23.0°	19	42.5° 43.0°	21.0°	1,940,000,000 2,180,000,000	0.5x10^{-10}
Continued (42.8°)	24	52.0° 52.5°	9.5°	2,480,000,000 2,600,000,000	....
5.0° 6.0°	24	25.0° 25.0°	19.5°	2,100,000,000 2,360,000,000	0.3x10^{-10}
Continued (25.0°)	24	38.0° 39.0°	13.5°	....	....
26.0° 27.0°	48	42.0° 42.5°	16.0°	1,150,000,000 1,260,000,000	....
23.0° 24.0°	24	30.0° 31.0°	7.0°	730,000,000 910,000,000	0.2x10^{-10}

*Michigan Agric. College Experiment Station Technical Bul. No. 10.

TABLE X.—*Development of Strain IV in Milk Repeatedly Neutralized.*

Series 1.

Acidity after each neutralization.	Time in hours.	Acidity after fermentation.	Increase of acid.	Number of bacteria.	Fermenting capacity.
(16.0°) fresh		89.0° 90.0°	74.0°	1,310,000,000 1,370,000,000	?
5.0° 6.0°	24	57.0° 59.0°	52.0°	1,170,000,000 1,220,000,000	1.7×10^{10}
Continued (58.0°)	5½	62.0° 64.0°	5.0°		
5.0° 5.5°	42	52.5° 53.0°	17.5°	1,360,000,000 1,470,000,000	0.8×10^{10}
—3.0° —3.0°	24	10.0° 10.5°	13.0°	780,000,000 830,000,000	0.5×10^{10}
Continued (10.3°)	24	13.0° 13.5°	3.0°	340,000,000	....
Continued (13.3°)	48	16.0° 17.0°	3.5°	80,000,000 140,000,000	....
Continued (16.5°)	24	20.0° 20.5°	4.0°		

Series 2.

Acidity after each neutralization.	Time in hours.	Acidity after fermentation.	Increase of acid.	Number of bacteria.	Fermenting capacity.
(16.0°) fresh	....	90.0° 89.0°	74.0°	2,010,000,000 2,120,000,000	
12.0° 13.0°	24	46.5° 49.5°	35.5°	1,570,000,000 1,610,000,000	0.8×10^{10}
Continued (48.0°)	5½	50.5° 51.5°	3.0°		
15.5° 16.0°	42	50.0° 50.5°	34.5°	1,410,000,000 1,570,000,000	0.5×10^{-10}
13.5° 14.5°	24	27.0° 27.0°	13.0°	1,220,000,000 1,290,000,000	0.4×10^{-10}
Continued (27.0°)	24	32.5° 33.5°	6.0°	1,070,000,000 1,110,000,000	0.2×10^{10}
Continued (33.0°)	48	39.5° 40.0°	7.0°	70,000,000 100,000,000	
11.0° 12.0°	29	13.5° 15.0°	3.0°	30,000,000 50,000,000	

neutralization, and then decreases very slowly with Strain II, while Strain IV proves to be more sensitive.

The conditions of these five series correspond largely to the conditions which Duclaux chose for his determinations of the "activity" (p. 3). His data cannot be compared with these however, since he paid no attention to the time element. His cultures were carried on for several weeks before the final acid was determined.

The general conclusions from these experiments are that old cultures of lactic bacteria ferment again, if the cause of the retardation, the acid, is removed. The amount of acid formed anew is less after each neutralization and there is soon a point reached where the acid formation ceases. This point varies with the different strains, No. II reaching the limit after having formed a total of about 360° acid, while No. IV stopped after having formed altogether about 200°. Another difference between these two strains is that the resistant Strain II showed an increase of bacteria after neutralization while Strain IV showed a decrease from the start. The fermenting capacity is lower in these five experiments than in a fresh culture and continuously decreasing, faster with Bact. IV than with Bact. II.

DEGENERATION OF OLD MILK CULTURES.

Another problem deserves attention in connection with the ageing of lactic cultures, namely the degeneration of starters by age. It is an old experience of butter-makers that starters lose their efficiency by long standing. Unless they are transferred daily, they acidify but slowly. It is well known, too, that milk cultures of *Bact. lactis acidi* die rapidly, and that laboratory cultures of this organism can be kept only by continuous transplanting or by refrigeration. Apparently, the prolonged action of the lactic acid has some unfavorable influence upon certain cell functions. In the following experiments, it will be shown that both the fermenting power and the reproductive power are reduced by age, i. e., by long exposure to their own products of metabolism. While in the former experiments, only the inhibitive cause was removed, in the following series the old culture is transferred to a fresh medium and, after transferring, the cells are not hindered further by their own products. Any differences occurring in such cultures will be inherited characters.

For the first experiment, a pure culture was isolated from the starter used in Table IV. The average fermenting capacity had been found to be 32.5×10^{-10}mg. This culture will be called Strain *a*. The experiment was carried on in the following way:

Twelve flasks containing 100 cc. of skimmed milk were sterilized and named in duplicate, *A*, *B*, *C*, *D*, *E* and *F*. *A* was inoculated with Strain *a* and served as stock culture. *B* and B_1 were inoculated from *A* after 24 hours, *B* with 0.01 cc., B_1 with 0.0001 cc. of *A*. After 2 days, *C* and C_1 were inoculated from *A*. After 4 days, *D* and D_1 were inoculated from *A*. These cultures *D* acidified but very slowly, compared with *B* and *C*, therefore in the next inoculation, after 7 days, the amount of inoculation was increased, *E* receiving 1 cc., and E_1 0.01 cc. of *A*. After 13 days, the last inoculation was made, *F* receiving 1 cc. of *A*.

In all these cultures, the bacteria were counted in the beginning and

after exactly 24 hours, with the exception of *F* which acidified so slowly that the first test was made after 36.5 hours, the second after coagulation at 60 hours. All results are compiled in the following two tables. The first one gives the numbers of bacteria and the acidities of the stock culture *A* at different days, the second shows the development of the sub-cultures.

TABLE XI.—*The Ageing of Culture A of Strain a.*

Age.	Cells per cc.	Acidity.
1 day	1,120,000,000 1,140,000,000 1,150,000,000	69.5°
2 days	870,000,000 882,000,000 889,000,000 980,000,000	100.0°
4 days	550,000,000 594,000,000	108.0°
7 days	127,000,000 131,000,000	114.0°
10 days	1,960,000 2,300,000 2,490,000 2,700,000	110.0°
13 days	3,500,000 3,700,000	?

Table XII shows plainly a reduction of the fermenting capacity as well as of the power of multiplication. The fermenting power of the average cell is reduced to about one-third or one-fourth of that of the original culture in good physiological condition. The rate of multiplication is not so very much affected at first, but after 7 days it is very evident and after 13 days, the cells seemed hardly able to grow at all, one cell after being transferred into fresh milk requiring 8 to 10 hours for dividing. Since both the fermenting power and the reproductive power are thus reduced to about one-fourth of their original activity, the efficiency of the old starter will be only one sixteenth of that of the fresh starter.

In looking at the colonies of the lactic bacteria on the gelatin counting plates, it was easy to be seen that not all cells had been affected in the same degree. The plates of young, vigorous cultures show all colonies fairly large and of the same size within three days. This is not at all true with the old cultures, the size as well as the rapidity of development is entirely different. As an illustration of this may be given the data from the plates of culture *A*, 13 days old. These plates were counted after 3 days and the duplicate plates showed 63 and 72 colonies of fairly good size. After 7 days, they were looked over again and a great number of all sizes of colonies, from the ordinary full size to hardly visible ones was found. Counting all that could possibly be seen with the naked eye, 3,500 and 3,700 were found on the duplicate plates.

This experience makes the exactness of counting doubtful, at least with old cultures. There will be perhaps a large number of colonies

so small that they cannot be seen with the naked eye, others may not develop at all in gelatin, while they may do so in milk. But the influence which this possible error will have on the results, does not affect the conclusions. If there are in old milk really more bacteria than we have counted, then the same amount of lactic acid would have been produced by a larger average number, that means the fermenting capacity of a single cell would be still smaller than recorded. The decrease of the fermenting capacity cannot be doubted, but perhaps the degree of the decrease may.

TABLE XII.—*Degeneration of Strain a in an Old Milk Culture.*

	Age of inoculum.	Number of cells.		Acidity.		Fermenting capacity.	Rate of reproduction (minutes).
		Beginning.	After 24 hours.	Beginning.	24 hours.		
B.	1 day	114,000	820,000,000 830,000,000 856,000,000	16.5°	81.0° 82.0°	38.4×10^{-10}	112
B_1.		1,140	655,000,000 677,000,000 590,000,000 760,000,000	16.5°	61.5° 63.0°	40.7×10^{-10}	114
C.	2 days	90,000	784,000,000 840,000,000 970,000,000	16.5°	80.0°	36.5×10^{-10}	109
C_1.		900	290,000,000 334,000,000 374,000,000	16.5°	33.0°	34.5×10^{-10}	78
D.	4 days	57,200	174,000,000 215,000,000	16.5°	28.0° 28.0°	26.1×10^{-10}	123
D_1.		572	24,000,000 46,000,000	16.5°	16.0° 18.0°	(?)	....
E.	7 days	1,290,000	812,000,000 812,000,000	15.0°	56.0°	17.9×10^{-10}	155
E_1.		12,900	79,000,000 82,000,000	14.0°	17.0°	17.6×10^{-10}	114
F....	13 days	3,600,000	*57,000,000 80,000,000	15.0°	22.0° 23.0°	12.1×10^{-10}	515
		(Continued).	†360,000,000 390,000,000	(22.5°)	55.0°	8.6×10^{-10}	679

*After 36.5 hours.
†After 60 hours.

This slow growth in gelatin and the small size of the colonies compared with those from young, fresh cultures is remarkable, if we consider the number of generations necessary to build up a colony. When the old culture *A* was transferred to the fresh sterile milk, the bacteria had the very best chance for multiplication. But they did not multiply readily. Then they were transferred to lactose gelatin, but even there the colonies developed slowly. In sample *E,* for instance, there were 12,900 cells in the beginning and 80,000,000 after 24 hours. This means eleven or twelve generations under the very best conditions of

life; and yet, in these 12 generations the bacteria had not yet recovered from the long sojourn in the old sour milk. Then this culture was transferred into gelatin, for counting. It takes about 20 generations to make from one cell a colony visible to the naked eye. But most of these colonies were so much smaller than those of the young, fresh cultures, that we must conclude even 30 generations have not been sufficient for the bacteria to recover. Similar phenomena are found when bacteria have been very nearly killed by poisons, and in an experiment carried on by the writer six years ago where bacteria had been exposed to 1,000 atmospheres of pressure, the colonies grew very slowly and never even approximated the size of the colonies in the control samples.

REGENERATION OF A DEGENERATED CULTURE.

It seemed worth while trying to ascertain how long a time and how many generations would be necessary for the old standard of growth and acid production to be reached again. To this end, a series of inoculations was made from *F* to *H*, from *H* to *I*, from *I* to *K* and from *K* to *L*. In all these cultures, the number of bacteria and the acid produced were determined, the results are given in Table XIII. With culture *H*, there must have been something wrong, since the acidity after the first 24 hours of growth rose so little in the following 12 hours. The culture *L*, inoculated with 0.01 cc. of the culture *K*, was coagulated in 20 hours and had after 24 hours, the high acidity of 83°. At this point, the experiment was discontinued under the supposition that the desired point had been reached. But this was not the case, for even in this last rapidly coagulating culture, the fermenting capacity was only half of what it had been before. The reason for this rapid coagulation was due to the larger number of cells per cc. The rate of multiplication was soon at the former standard of the original culture, or had even increased.

TABLE XIII.—*Regeneration of the Degenerated Strain a.*

	Beginning.		24 hours.			36 hours.		
	Number.	Acidity.	Number.	Acidity.	Fermenting capacity.	Number.	Acidity.	Fermenting capacity.
H......	6,800	14.0°	269,000,000 295,000,000	22.0° 22.0°	20.6×10^{-10} mg.	Lost..........	33° 35°	....
	68	14.0°	144,000,000 160,000,000	17.0° 17.0°	15.6×10^{-10} mg.	384,000,000 426,000,000	27° 27°	14.2×10^{-10} mg.
....	40,500	18.5°	....	....	....	1,140,000,000 1,220,000,000	78° 79°	18.6×10^{-10} mg.
K......	118,000	18.5°	*1,380,000,000 1,610,000,000	52.5° 54.5°	8.2×10^{-10} mg.	....	....	....
	1,180	18.5°	*399,000,000 419,000,000	24.0° 25.0°	9.7×10^{-10} mg.	....	....	....
L.........	150,000	18.5°	1,650,000,000 2,070,000,000	82.0° 84.0°	17.6×10^{-10} mg.	....	....	....

*25 hours.

We obtain the following numbers for the rate of reproduction:

H........ 94 minutes in 24 hours.
68 minutes in 24 hours.
I.........146 minutes in 36 hours.
K.........110 minutes in 24 hours.
81 minutes in 24 hours.
L.........106 minutes in 24 hours.

The three best comparable numbers of H, K, and L, which were gotten by the same dilutions, 94, 110 and 106, agree fairly well. But in all, the results do not check nearly as well as in those of the young cultures. That is not surprising; we have here the same experience which every plant breeder has; by continuous cultivation under nearly the same conditions a very homogenous strain is obtained. If no more care is given to this strain, it will lose the homogenicity, all kinds of varieties are found, and it takes a large number of generations to make up for the degeneration in a comparatively short time. In this particular case, a new type had been formed from Bacterium *A*, a fast growing, but slowly fermenting organism.

TABLE XIV.—*Degeneration of Strain II.*

	Age of culture.	Number per cc.		Acidity.		Fermenting capacity. mg.
		Beginning.	After 24 hours.	Beginning.	24 hours.	
A....	....	12,400 13,800	1,350,000,000 1,800,000,000	17.0°	79.0° 79.5°	$25.0x10^{-10}$
B.	1 day..................................	157,000	1,420,000,000 1,580,000,000	17.0°	77.0° 79.5°	$20.2x10^{-10}$
B.[1]		1,570	1,180,000,000 1,280,000,000	17.0°	69.0° 69.0°	$30.5x10^{-10}$
C.	5 days..................................	2,800,000	1,730,000,000 1,850,000,000	17.0°	Lost.	....
C.[1]		28,000	1,100,000,000 1,150,000,000	17.0°	Lost.	....
D.	9 days..................................	less than 1000	*1,350,000,000 1,580,000,000	17.0°	*78.0° 79.0°	$16.3x10^{-10}$
D.[1]		less than 10	1,480,000,000 *1,510,000,000	17.0°	70.0° 70.5°	$18.2x10^{-10}$
E....	12 days..................................	between 1 and 100	†1,600,000,000 1,630,000,000	17.0°	†72.0° 72.5°	$13.2x10^{-10}$

*48 hours.
†73 hours.

The experiment on the degeneration of lactic bacteria in milk was repeated with Strain II, with the same result. The decrease of the fermenting capacity was not as great as with Strain *a*, but quite distinct. The number of bacteria in the stock culture A decreased faster than was

expected, and therefore the initial counts of D and E are rather uncertain. In culture C, the size of the colonies showed the same variations mentioned in the preceding experiments, and the variations increased with the age of the culture.

VI. THE INFLUENCE OF FOOD.

It seems reasonable to suppose *a priori*, that the fermenting capacity will be influenced by the food. It is well known that *Bacterium lactis acidi* produces less acid in sugar broth than in milk. It is also known that certain strains produce larger amounts of acid in milk after the addition of peptone. Whether this is due to a faster multiplication or to an increase in the fermenting power of the single cell can be ascertained by computation of the fermenting capacity.

The Influence of Peptone.—Experiments concerning the influence of peptone were carried on with the Strains II and IV. While Strain II shows very little influence (Table XV) Strain IV reacts promptly by a much faster and more vigorous acid formation (Tables XVI and XVII). All these experiments were arranged in the same way. 100 cc. portions of milk were sterilized discontinuously in Erlenmeyer flasks, some of them receiving 1 g. of peptone (Witte) before the first heating. The sterile flasks were inoculated with a measured amount of a young milk culture of the strain under study. In the first two experiments, duplicates were made, the difference consisting only in the amount of inoculum. In the experiment with Strain II (Table XV) the acidity and the bacterial counts were taken every 12 hours, and with Strain IV which develops much more slowly the data were obtained every 24 hours. The experiments with Strain IV were carried out by Mr. C. F. Barnum.

TABLE XV.—*Influence of Peptone upon Strain II.*

Hours.	Milk.				Milk + 1 per cent peptone.			
	Bacteria per cc.	Acidity.	Rate of growth (minutes).	Fermenting capacity.	Bacteria per cc.	Acidity.	Rate of growth (minutes).	Fermenting capacity.
0	60,000	19.5°	....	....	60,000	23.0°	....	....
12	234,000,000 241,000,000	24.0° 24.5°	60	17.9×10^{10}	172,000,000 181,000,000	25.5° 26.0°	63	13.3×10^{10}
24	1,190,000,000 1,390,000,000	67.5° 68.5°	295	7.6×10^{-10}	1,220,000,000 1,240,000,000	77.5° 77.5°	257	10.3×10^{10}
37	....	76.0° 78.5°	....	....	....	84.5° 85.5°	....	....
0	600	19.5°	....	....	600	23.0°	..	
12	....	19.5°	....	....	....	22.0° 23.0°	....	....
24	1,050,000,000 1,250,000,000	51.0° 52.0°	69	21.8×10^{10}	1,030,000,000 1,190,000,000	53.5° 54.5°	69	21.7×10^{10}
37	1,210,000,000 1,330,000,000	75.0° 75.5°	....	1.4×10^{-10}	1,200,000,000 1,410,000,000	82.5° 83.5°	....	1.8×10^{10}

Table XV shows that Strain II is affected very little if at all by the peptone. The acidities of the peptone-milk are a little higher than those of the plain milk, because the peptone has an acidity of its own, about 3°-4°. The difference in the fermenting capacities in the two duplicates is within the limits of error. The rate of growth also shows no difference. The final acidity of the peptone-milk is about 8° higher than that of the check, otherwise the four cultures are as much alike as can be expected in parallel cultures.

Quite different is the action of peptone upon Strain IV. The slow development is illustrated by the fact that the milk cultures did not coagulate in 48 hours, and after 72 hours the acidity was lower than with Strain II after 24 hours. The peptone-milk cultures, however, acidified much faster even than Strain II, and the final acidity is twice as high as that of the plain milk culture. The counts of the bacteria show about five times as many bacteria in the peptone-milk, indicating a faster multiplication in the presence of peptone. This is substantiated by the computation of the rate of reproduction. The time required for one cell to produce two cells in plain milk compared with peptone milk is 118 against 99, 82 against 70 and 78 against 68 minutes in the three experiments. In every case, the reproduction requires less time in the presence of peptone.

TABLE XVI.—*Influence of Peptone upon Strain IV.*

Hours.	Milk.				Milk + 1 per cent peptone.			
	Bacteria per cc.	Acidity.	Rate of growth (minutes).	Fermenting capacity.	Bacteria per cc.	Acidity.	Rate of growth (minutes).	Fermenting capacity.
0........	124,000	16.0° 16.0°	....	....	124,000	19.0° 19.0°	....	....
24.......	520,000,000 590,000,000 640,000,000 680,000,000	29.5° 30.0°	118	10.5×10^{10}	2,930,000,000 2,870,000,000	102.0° 103.0°	99	15.7×10^{-10}
48	559,000,000 577,000,000 590,000,000 660,000,000	45.0° 47.0°	....	1.0×10^{-10}	2,240,000,000 2,570,000,000	103.0° 104.0°	....	0
72......	710,000,000 790,000,000	56.0° 56.0°	....	0.6×10^{-10}	....	116.0° 116.0°	....	0.2×10^{-10}
0........	1,240	16.0° 16.0°	....	....	1,240	19.0° 19.0°	....	....
24.......	265,000,000 270,000,000 280,000,000 290,000,000	24.0° 24.5°	82	19.9×10^{-10}	1,820,000,000 1,940,000,000	61.5° 62.0°	70	17.5×10^{10}
48.......	360,000,000 435,000,000 465,000,000 470,000,000	38.5° 39.0°	....	1.6×10^{-10}	2,510,000,000 3,240,000,000	107.5° 109.5°	....	0.8×10^{10}
72......	550,000,000 610,000,000	49.5° 50.0°	....	0.8×10^{-10}	....	124.0° 124.5°	....	0.2×10^{-10}

TABLE XVII.—*Influence of Peptone on Strain IV.*

Hours.	Milk.				Milk + 1 per cent peptone.			
	Bacteria per cc.	Acidity.	Rate of growth (minutes).	Fermenting capacity.	Bacteria per cc.	Acidity.	Rate of growth (minutes).	Fermenting capacity.
0	1,200	19.0° / 19.0°	....	....	1,200	25.0° / 25.5°	....	....
24	422,000,000 / 430,000,000	30.5° / 31.0°	78	19.0×10^{-10}	2,410,000,000 / 2,760,000,000	94.0° / 96.5°	68	21.4×10^{-10}
48	394,000,000 / 380,000,000	48.0° / 48.0°	....	1.6×10^{-10}	2,510,000,000 / 2,560,000,000	105.0° / 112.0°	....	0.2×10^{-10}
72	425,000,000 / 433,000,000	59.0° / 59.5°	....	1.0×10^{-10}	1,630,000,000 / 1,750,000,000	126.0° / 129.0°	....	0.3×10^{-10}

The fermenting capacity is higher in two cases with peptone and in one case without peptone, and the differences are not very pronounced, so it seems quite safe to state that the fermenting power of each cell was not altered materially while the reproduction was stimulated decidedly. The most remarkable effect produced by the peptone, however, remains unexplained. namely the higher number of bacteria and the higher final acidity. It is generally assumed that fermentation ceases because the products of fermentation interfere with a continued activity of the fermenting enzyme. If Strain IV normally ceases to ferment at 60° acid, why does it produce twice that amount in the presence of peptone? And why does only Strain IV show this difference while Strain II does not. The question could be solved by the assumption that in the presence of peptone, a more resistant lactacidase is formed, but another simpler explanation is possible, based on the law of mass action. It is known that, at least with some enzymes, the enzymic action will reach an equilibrium. If this equilibrium is disturbed by further addition of enzyme, enzymic action will continue for a certain time. In the case of Strain II, the number of cells and the amount of enzyme per cell was found to be constant. consequently there is a constant amount of acid produced. In the case of Strain IV, the number of cells in one sample is five times as high as in the other. The individual cells of each of the two samples were found to contain approximately the same amount of enzyme, consequently there is five times as much enzyme in the one flask as in the other. Under these conditions, the equilibrium in the two flasks cannot be expected to be the same. It is by no means certain, however, that the law which is found true with a few enzymes holds true with all of them, and it seems still doubtful whether the amount of fermentation products in a culture can be increased by adding large quantities of cells.

The increase in the number of bacteria by the addition of peptone does not agree with the common assumption that the number of cells is limited by the accumulation of fermentation products. An explanation seems possible which at the same time helps to account for the results in another experiment. Strain II is not affected by peptone, so we must conclude it is able to provide for its nitrogenous matter in some other way, or it is not able to use peptone. Its development in milk seems to be

checked largely by the acid formed. Strain IV grows scantily in skimmed milk, but reproduces abundantly when peptone is added; the soluble nitrogenous compounds seem to be the limiting factor for this strain. This agrees with the results of the Tables VIII, IX, X, where pure cultures of these two strains in milk were neutralized; Strain II showed an increase in number after neutralization indicating that it was largely the acid which interfered with the growth, while Strain IV did not multiply further even after the acid had been neutralized; lack of available nitrogenous food seems to be a reasonable explanation for the behavior of Strain IV.

The observation of Marshall[1] and Marshall and Farrand[2] that certain bacteria are able to stimulate the acid formation of certain lactic bacteria, can be to some extent accounted for by the preparation of nitrogenous food for the lactic bacteria. Marshall himself has supposed this to be one of the possible explanations. The behavior of the Strains II and IV in mixed cultures make this explanation quite probable. Strain II showed in no case any appreciable increase of acidity in association, while Strain IV gave the following results:

TABLE XVIII.—*Associative Acid Production.*

Cultures.	Fresh.	24 hours.	48 hours.	96 hours.
Bact. lactis acidi IV alone	21°	51°	80°	95°
Bact. lactis acidi IV + B. mycoides	21°	66°	90°	93°
Bact. lactis acidi IV + B. prodigiosus	21°	58°	99°	113°
Bact. lactis acidi IV + B. subtilis	21°	58°	81°	92°
B. mycoides alone	21°	26°	27°	31°
B. prodigiosus alone	21°	31°	35°	36°
B. subtilis alone	21°	22°	22°	21°

The Influence of the Absence of Sugars.—In this discussion of the ininfluence of food upon the fermenting capacity must be included the degeneration of lactic bacteria in sugar-free or sugar-poor media. To see whether such degeneration could be produced by continued transplanting in broth, Strain *a* was transferred into a tube of meat-peptone broth, from this culture to a second tube and so on. The transfers were made daily. From the first, second, sixth and tenth cultures, milk was inoculated and the numbers and acidities of these milk cultures were determined at the beginning and after 24 hours. The result is given in the Table XIX.

There is a great variation in the fermenting capacity of the duplicates of the first two transfers which might be accounted for by the influence of the change of medium. After 6 days' continuous transplantation from broth to broth, the culture became adapted to the medium and the results are homogenous. Since the inoculum was not the same in every case, the first cultures of *A* and *B* and the second cultures of *C* and *D*

[1]Centralbl f. Bakt. II, Bd. 11, p. 739.
[2]Mich. Agric. College Special Bul. 42.

TABLE XIX.—*Degeneration of Strain a in Broth.*

Number of broth culture.	Number of cells.		Acidity.		Fermenting capacity.	Rate of reproduction.
	Fresh.	24 hours.	Fresh.	24 hours.		
A.— 1	3,750	1,430,000,000 1,520,000,000	18.0°	69.0° 69.0°	24.1×10^{-10}	77 min.
	37	509,000,000 513,000,000	18.0°	20.0° 19.5°	3.1×10^{-10}	61 min.
B.— 2	3,200	1,690,000,000 1,950,000,000	18.0°	77.0° 81.0°	28.2×10^{-10}	64 min.
	32	860,000,000 900,000,000	18.0°	34.0° 35.0°	16.8×10^{-10}	58 min.
C.—6	181,000	1,870,000,000 1,990,000,000	16.5°	81.0° 82.0°	16.9×10^{-10}	108 min.
	1,800	1,820,000,000 1,820,000,000	16.5°	54.0° 54.0°	15.4×10^{-10}	72 min.
D.—10	235,000	2,510,000,000 2,730,000,000	16.5°	82.0° 84.0°	12.8×10^{-10}	107 min.
	2,350	600,000,000 700,000,000	16.5°	29.0°	13.0×10^{-10}	80 min.

are most comparable, having about the same number of cells in the start. There seems to be a decrease in the fermenting capacity, the numbers being 24, 28, 15, and 13 respectively. The rate of production does not seem altered, the respective times being 77, 64, 72, and 80 minutes.

One instance is very noticeable especially in the first transfers, namely that the cultures with small inoculum show a lower fermenting capacity than the ones with large inoculum. In all previous experiments where duplicates with different amounts of inoculation were tried, the smaller inoculum showed the higher fermenting capacity because it was determined at an earlier stage of development, before the retarding influence of the accumulating compounds became so noticeable. See the beginning of subtitle V. The difference in this experiment is very striking.

Another experiment was carried on in the same way with Strain II, but in this case the broth was made sugar-free by growing *B. coli* in it according to the Standard Methods of Water Analysis. At the same time, a parallel culture was transferred daily in milk as a check, and sub-cultures of this check were made corresponding to the sub-cultures from broth. The growth of the bacteria in the sugar-free broth was hardly visible, and at first 1 cc. of the 24-hour culture was transferred to the next tube. But after a few days' trial, one loopful was found to be sufficient. The experiment was carried on for 31 days, and then was given up because the fermenting capacity of Strain II did not seem to be in the least affected.

The only distinct difference in the behavior of the broth and milk transfers is the fact that in the duplicates from the broth culture, the smaller inoculum causes the smaller fermenting capacity while in the milk transfers, the opposite is true in every case. It is not easy to give a satisfactory explanation for this unless we suppose that in sugar-free broth bacteria lose the power of producing the acid-forming enzyme to a large extent, and it takes several generations to bring this power back to the original standard.

For the study of the literature on degeneration of lactic bacteria in various media, see Weigman's article in Lafar's Handbuch der Technischen Mycologie, Vol. II, p. 101.

TABLE XX.—*Degeneration of Strain II in Sugar-free Broth.*

Number of broth transfers.	Number of bacteria per cc.		Acidity.		Fermenting capacity.
	Beginning.	After 24 hours.	Beginning.	24 hours.	
A.—1	2,300	1,440,000,000 1,560,000,000	17.0°	65.0° 67.0°	$23.7x10^{-10}$
	23	870,000,000 880,000,000	17.0°	32.5° 32.5°	$16.8x10^{-10}$
B.—3	550	1,520,000,000 1,620,000,000	17.0°	58.0° 59.0°	$21.3x10^{-10}$
	6	321,000,000 340,000,000	17.0°	21.0° 20.5°	$11.1x10^{-10}$
C.—6	920	1,370,000,000 1,460,000,000	17.0°	64.0° 63.0°	$25.4x10^{-10}$
	9	280,000,000 317,000,000	17.0°	23.5° 24.0°	$21.2x-10^{-10}$
D.—10	950	1,150,000,000 1,480,000,000	17.0° 17.0°	62.0° 62.0°	$26.1x10^{-10}$
	10	280,000,000 304,000,000	17.0° 17.0°	25.0° 25.0°	$25.5x10^{-10}$
E.*—16	1,090	1,620,000,000 1,680,000,000	13.0°	50.0° 51.0°	$15.0x10^{-10}$
	11	249,000,000 268,000,000	13.0°	16.0° 16.5°	$9.4x10^{-10}$
F.—22	905	1,650,000,000 1,790,000,000	13.0°	61.0° 62.0°	$22.6x10^{-10}$
	9	450,000,000 520,000,000	13.0°	20.5° 21.0°	$15.4x10^{-10}$
G.—31	925	1,330,000,000 1,450,000,000	18.5°	56.0° 56.5°	$21.0x10^{-10}$
	9	300,000,000 340,000,000	18.5°	25.5° 25.5°	$20.5x10^{-10}$

*28 hours old.

TABLE XXa.—*Check Transfers in Milk.*

Number of milk samples.	Number of bacteria per cc.		Acidity.		Fermenting capacity.
	Beginning.	After 24 hours.	Fresh.	24 hours.	
B.—3	193,000	1,400,000,000 1,410,000,000	17.0°	75.5° 76.0°	$20.1\text{x}10^{-10}$
	1,930	1,190,000,000 1,580,000,000	17.0°	64.5° 65.0°	$25.2\text{x}10^{-10}$
C.—7	183,000	1,350,000,000 1,640,000,000	17.0°	72.5° 74.5°	$18.6\text{x}10^{-10}$
	1,830	1,340,000,000 1,430,000,000	17.0°	70.0° 71.0°	$28.3\text{x}10^{-10}$
D.—11	132,000	1,520,000,000 1,660,000,000	17.0°	71.5° 72.5°	$18.0\text{x}10^{-10}$
	1,320	1,040,000,000 1,090,000,000	17.0°	43.0° 43.0°	$18.4\text{x}10^{-10}$
E.—18	134,000	1,590,000,000 1,780,000,000	13.0°	66.0° 67.0°	$16.6\text{x}10^{-10}$
	1,340	1,570,000,000 1,760,000,000	13.0°	52.5° 53.0°	$18.1\text{x}10^{-10}$
F.—23	186,500	1,890,000,000 1,980,000,000	13.0°	66.0° 66.0°	$13.7\text{x}10^{-10}$
	1,865	1,000,000,000 1,080,000,000	13.0°	61.5° 62.5°	$33.8\text{x}10^{-10}$

Degeneration of old broth-cultures.—Since the two tested strains of lactic bacteria do not show much degeneration if transferred daily in sugar-free media, it was tried in the following experiments whether a continued sojourn in the sugar-free medium might have a more pronounced influence. The following two series, with strains II and IV, were carried out by Mr. W. W. Shanor. The milk culture was transferred several times in sugar-free broth, and from the last transfer three flasks each containing 100 cc. of sugar-free broth were inoculated. After certain time intervals, 1 g. of sterile lactose was added to these cultures and growth and acid formation were followed closely. This method of adding lactose is better than the transferring into milk practiced in the above experiments since the latter introduces a new factor, the change of medium.

The results are given in Tables XXI and XXII. Strain II shows no change whatever in the fermenting capacity in 6 days; strain IV showed

TABLE XXI.—*Old Broth Cultures after Addition of Lactose: Strain II.*

Age of broth culture.	Time after adding lactose.	Bacteria per cc.	Acidity.	Fermenting capacity.
2 days	0 hours.	7,500,000 7,800,000	22.5° 22.5°	....
	16 hours.	346,000,000 369,000,000	45.5° 46.0°	$20.7x10^{-10}$
	24 hours.	350,000,000 350,000,000	50.5° 52.0°	$1.8x10^{-10}$
	48 hours.	....	56.0° 56.0°	$0.6x10^{-10}$
4 days	0 hours.	5,000,000 5,600,000	21.5° 21.5°	....
	16 hours.	247,000,000 277,000,000	42.0° 42.5°	$25.6x10^{-10}$
	24 hours.	279,000,000 280,000,000	49.0° 50.0°	$3.2x10^{-10}$
	48 hours.	....	55.0° 58.0°	$1.0x10^{-10}$
6 days	0 hours.	5,500,000 6,700,000	22.0° 22.0°	....
	16 hours.	292,000,000 311,000,000	49.0° 49.5°	$29.1x10^{-10}$
	24 hours.	397,000,000 396,000,000	55.0° 55.0°	$1.5x10^{-10}$
	72 hours.	....	69.5° 70.0°	$0.5x10^{-10}$

little difference after 2 and 4 days, so the last flask was kept for 21 days. In this time, a decided decrease in the number of bacteria had taken place, and the multiplication after the addition of lactose was not very rapid. No acid was formed in the first 16 hours, but this cannot be accounted for by a lack of fermenting capacity. The number of cells is so small that the total acid produced in 16 hours could not be detected by titration. It amounts to only 0.2°. From 16 to 24 hours, the fermenting capacity is normal.

The experiments show plainly the necessity of sugar for abundant growth of the lactic organisms. The final number per cc. reached in the absence of sugar was 7,000,000 and 20,000,000 respectively. Addition of lactose raised these numbers to 350,000,000 and 600,000,000. The long sojourn in sugar-free broth has very little degenerating influence compared with the action of milk (Tables XII and XIV).

TABLE XXII.—*Old Broth Culture after Addition of Lactose: Strain IV.*

Age of broth culture	Time after adding lactose.	Bacteria per cc.	Acidity.	Fermenting capacity.
2 days	0 hours.	10,200,000 13,500,000	22.5° 22.5°	
	16 hours.	591,000,000 594,000,000	47.0° 47.5°	$13.2x10^{-10}$
	24 hours.	530,000,000 540,000,000	53.5° 53.5°	$1.3x10^{-10}$
4 days	0 hours.	21,600,000 22,800,000	22.5° 22.5°	. . .
	16 hours.	435,000,000 455,000,000	36.0° 36.5°	$7.9x10^{-10}$
	24 hours.	669,000,000 683,000,000	49.5° 50.0°	$0.8x10^{-10}$
21 days	0 hours.	300,000	22.5° 22.5°	
	16 hours.	66,000,000	22.5° 22.5°	
	24 hours.	415,000,000	38.5° 39.0°	$13.9x10^{-10}$
	48 hours.	....	55.5°	$1.6x10^{-10}$

VII. THE INFLUENCE OF TEMPERATURE.

The formation of acid by lactic bacteria is known to be caused by an enzyme, lactacidase. This enzyme remains within the cell, but it acts largely independent of the cell that produced it, and may continue its activity even after the death of the cell. Enzymes have their maximum, optimum, and minimum temperatures. Whether or not the optimum temperature of the enzyme and the optimum temperature of growth coincide, has never been determined. It is possible, but not necessary. The determination would be very difficult unless the computation method is used. Even then, the experiments would require much time. A series of incubators for parallel experiments would be indispensable.

The only data on the influence of higher temperatures upon the development of the lactic bacteria are the following two experiments carried on in the dairy laboratory of the University of Göttingen, six years ago, with the assistance of Professor R. Iwazumi, now in Morioka, Japan.* Table XXIII gives the data obtained with a very slow growing bacterium in lactose broth at 35°C.

*A few other experiments by Professor Iwazumi are not published here except in the averages of all strains in Table VI.

TABLE XXIII.

Age.	Number per cc.	Increase of acid.	Fermenting capacity.
0 hours	100	....	....
48 hours	46,000,000	93.6 mg.	81.0×10^{-10}
72 hours	50,000,000	68.4 mg.	5.7×10^{-10}
120 hours	30,000,000	72.0 mg.	4.0×10^{-10}

The fermenting power of the same organism at 20° was found to be 24×10^{-10}. The increase of 15°C. has increased the fermenting capacity to nearly four times its normal amount.

In another experiment, tripilicate milk cultures were kept at 30°C. and tested every six hours. The result is shown in Table XXIV. The variation in the fermenting capacity for the first six hours is readily accounted for by the inaccuracy of the titration. The total amount of acid formed during the first six hours is practically within the limits of error which makes the data unreliable.

TABLE XXIV.

Hours after inoculation.	1.		2.		3.	
	Acidity.	Number of bacteria.	Acidity.	Number of bacteria.	Acidity.	Number of bacteria.
0	18.4°	17,700	18.4°	17,700	18.4°	17,700
6	22.0°	95,700,000	20.4°	115,500,000	20.0°	180,500,000
12	48.0°	6,660,000,000	54.4°	6,120,000,000	54.0°	6,700,000,000
24	96.8°	5,400,000,000	95.6°	5,300,000,000	98.4°	6,480,000,000

These numbers give the following fermenting capacity:

Hours.	1.	2.	3.
0– 6 hours	70.0×10^{-10}	32.9×10^{-10}	17.7×10^{-10}
6–12	3.6×10^{-10}	5.1×10^{-10}	4.3×10^{-10}
12–24 hours	0.6×10^{-10}	0.5×10^{-10}	0.5×10^{-10}

No records are on hand to compare these data with those obtained at room temperature. The rate of reproduction is decidedly decreased, only 25 to 29 minutes being required for one cell division during the first six hours.

The data on the influence of temperature are too incomplete to allow any detailed conclusions. The increase of the fermenting capacity with the temperature is evident. It is the object of this paper to point out

the possibilities of the application of the fermenting capacity rather than to exhaust the subject.

One of the most interesting chapters, the influence of oxygen, cannot be discussed because the few data obtained do not suffice for any conclusions. It is the author's aim to present this paper more as a suggestion than as a fact. It has been mentioned already that there is chance for improvement in the mathematical formula. Other criticisms might be made on the interpretation of some doubtful points. But altogether, the principal idea seems to be a valuable means to obtain information about cell life which, without this method, can not be obtained.

CONCLUSIONS.

It is possible to compute the amount of acid formed by a single bacterium cell in one hour, accurately enough to recognize decided changes in the fermenting capacity.

The computation requires nothing but the number of bacteria at the beginning and the end of the experiment, the time of the experiment and the acid formed in this time. All these data can be determined easily by the customary laboratory methods.

The amount of acid formed by one cell[1] in one hour was found to be in young milk cultures in the average of 57 determinations with various strains, 0.0,000,000,018 mg. or 18×10^{-10} mg. This is approximately the weight of one single cell.

There is no experiment on record to prove that in the first stage of development the multiplication takes place without fermentation. As soon as a determination of fermentation products is possible, it shows the fermentation per cell to be the faster the younger the culture.

There is a distinct difference in the fermenting capacity of different strains. The weakest strain had an average fermenting capacity of 7.4×10^{-10} while the strongest strain averaged 32.5×10^{-10} mg. per cell and hour.

The fermenting capacity decreases with the age of the culture, and even if the acid is neutralized the fermenting capacity is lower though fermentation takes place again. Old cultures acidify slowly, even if transferred into fresh milk, the rate of multiplication is also influenced by long sojourn in the same culture.

Peptone stimulates the acid formation of certain strains, but only by increasing their numbers while the amounts of acid per cell remain unaltered. Other strains show no material influence of peptone. In sugar-free broth, they develop very slowly, but the fermenting capacity is normal if lactose is added.

Temperature influences the fermenting capacity very decidedly.

[1]As counted by the plate method.

DIVISION OF BACTERIOLOGY AND HYGIENE.

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BY ZAE NORTHRUP.

FOREWORD.

Producers of milk and sanitary officers are not infrequently confronted with the disposition of milk which is under suspicion because of possible typhoid infection. Creameries and cheese factories as well as fermented milk drinks have been suggested as outlets where other means, as pasteurization, or other avenues are closed. Accordingly, the concrete subject, bearing upon the viability of *B. typhosus* in milk undergoing lactic fermentation, is advanced. It is the purpose of this bulletin to answer the questions involved in this subject as fully as is possible.

The variability in the actions of varieties of lactic organisms upon *B. typhosus* proves exceedingly interesting and pertinent. *Bact. bulgaricum* with its high acid qualities does not seem proportionately as effective as the more common types of lactic organisms.

CHARLES E. MARSHALL.

61

THE INFLUENCE OF THE PRODUCTS OF LACTIC ORGANISMS UPON BACILLUS TYPHOSUS.

This study was undertaken primarily for the purpose of establishing the maximum longevity of the typhoid bacillus in sour milk, but from necessity, it has involved problems of technique.

Previous investigations have dealt mostly with the longevity of *B. typhosus* in sweet milk; a few only, with sour milk, buttermilk, butter and cottage cheese.

Concerning the longevity of *B. typhosus* in sour milk, buttermilk, etc., Barthel[2] says: "Typhoid bacteria increase in milk and remain alive for twenty-five days without a decrease in number due to the formation of acid in the milk," and further "they themselves contribute to this acid production." "In butter, typhoid bacteria are found after ten days, especially in butter which is strongly acid, as this enclosed sour brine is a good nourishing medium."

On the other hand, Bassenge[10] has attempted to show that during the process of cream ripening, the lactic acid produced by fermentation organisms serves to diminish the number of typhoid bacilli present in the cream; and after the cream is thoroughly ripened and churned, the butter after being worked will contain no living typhoid organisms."

The greater number of investigators agree that the lactic fermentation in milk has a deleterious effect, both upon the vitality and longevity of the typhoid bacillus. According to Bassenge,[10] Behla[3] and others, when milk, buttermilk, etc., reaches 0.4 per cent lactic acid, typhoid bacilli are killed within 24 hours, although Fränkel and Kister found them living even after 48 hours.

It has been the purpose of the author to deal with the life of *B. typhosus* in sour milk only, limiting the problem in the first experiments to the ascertaining of the amount of lactic acid necessary to check, diminish the number of, or entirely destroy them.

In a preliminary test, measured portions of lactic acid were added to a definite volume of sweet milk in order to produce varying amounts of acid milk in which to grow the typhoid organisms. After a thorough test, this procedure was pronounced unsatisfactory as the addition of any quantity of acid diluted the milk and produced a curd quite dissimilar to that produced by lactic organisms; then, too, other products of lactic fermentation would not be present in this case to influence results; also, when adding pure lactic acid to milk a certain amount combines with the casein, leaving only a portion of the total acid free to act upon the organisms.

Experiment I.

LITMUS LACTOSE CALCIUM CARBONATE AGAR MEDIUM.

In the following test, the lactic organisms were allowed to produce their own acid and *B. typhosus* was grown in association with it in sterile milk. Plates were made from time to time as the milk was souring to determine the increase or decrease of typhoid bacilli.

It was not possible to adhere to natural conditions for the development of typhoid bacilli introduced, as the lactic organisms growing in milk, their most favorable nutrient medium, soon outnumbered the typhoid bacilli, necessitating consequently high dilutions for satisfactory plating; the comparatively few typhoid bacilli entering through natural infection would be lost sight of entirely in this way. Because of this condition, the milk was inoculated with a large number of the typhoid organisms and with comparatively few of the lactics.

After a few hours incubation, plates were made in ordinary agar from the combined culture. The 24-hour colonies on these plates were indistinguishable from one another unless microscopic examinations were made.

At this point, it was evident that a medium for differentiating the typhoid and lactic organisms was necessary. To this end, litmus lactose agar containing calcium carbonate in suspension was tried for plating.

This experiment was carried out at some length to determine the efficiency of the special plating medium.

Method of Procedure.—The agar for this experiment was made according to the methods advocated in the "Standard Methods of Water Analysis, 1904," for the preparation of litmus lactose agar.

To the clear filtered agar was added 1 per cent of a solution of Merck's purified litmus and washed calcium carbonate in the proportion of 3 grams to 100 cc. of agar.* This was stirred until the calcium carbonate was in even suspension throughout the agar, which was then immediately tubed and sterilized.

The medium for the typhoid-lactic culture was freshly separated milk obtained from the college dairy. Its acidity to phenolphthalein was tested and recorded. Each lot of milk was +15°.

200 cc. of the milk was poured into each of several 375 cc. Erlenmeyer flasks and sterilized. Fresh broth cultures of *B. typhosus* and the lactic organism were used in inoculating the milk flasks.

The broth cultures were transferred to the milk flasks by means of sterile 1 cc. pipettes. Dilutions for plating and counting were made in sterile salt solution.

Plates were made directly from the broth cultures in order to determine the number of typhoid and lactic organisms introduced.

After inoculation, the milk flasks were placed in the incubator at 37°C. Having previously found that *B. typhosus* persists in milk after curding, the flasks were allowed to remain in the incubator until the milk had curded, before plating.

The acidity of the milk at the time of plating was determined, and recorded with the day and the hour of plating.

The counts are recorded in the number of organisms per cc. of milk.

Colonies which could not be differentiated were identified by their characteristic growths on other media and by microscopical examination.

The culture of *B. typhosus* used in the following experiments was transferred from the laboratory stock culture and *Bact. lactis acidi* (lab.) was isolated from sour milk by one of the laboratory assistants.

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*In preparing a second lot of agar, calcium carbonate in the proportion of 1 gram to 100 cc. of agar was found to give sufficient density and enable the subsurface colonies to be seen more easily.

In Tests Nos. I to VI inclusive, litmus lactose agar having calcium carbonate in suspension, was used for plating.

TABLE I.

DIFFERENTIAL COUNTS ON LITMUS LACTOSE AGAR + $CaCO_3$

Number of test.	Age of combined culture.	Acidity of culture at time of estimate.	Number of bacteria in each cubic centimeter of milk at the times specified.	
			B. typhosus.	*Bact. lactis acidi (lab.)*
I	0 hours	15°	181,688	20,688
	22 hours	67°	1,000,000	717,500,000
II	0 hours	15°	3,750,000	130,000
	16.5 hours	49°	2,375,000	65,575,000
	19 hours	59°	2,800,000	136,675,000
III	0 hours	15°	1,260,850	149,625
	17¾ hours	57°	1,375,000	112,470,000
	22¼ hours	66°	20,000	25,200,000
	40½ hours	73°	None.	6,675,000
IV	0 hours	15°	3,375,000	134,125
	22¾ hours	60°	1,100,000	229,170,000
V	0 hours	15°	86,250	328,540
	43 hours	75°	None.	136,750,000
	48 hours	76°	None.	49,000,000
VI	0 hours	15°	325,415	351,500
	18½ hours	69°	5,500,000	695,500,000
	23½ hours	79°	None.	166,470,000

From the counts recorded above, it may be concluded that the acid produced by the lactic organism has an inhibitive influence upon the typhoid bacteria. The conditions, however, under which this experiment was performed were not wholly satisfactory, and the above conclusion can not be deemed as final.

The litmus lactose agar containing calcium carbonate was not wholly satisfactory as a differentiating medium because of the difficulty in counting the typhoid colonies. The sub-surface colonies were often-times scarcely discernible on account of the suspended particles of the calcium salt. The surface colonies of *B. typhosus* were moist, translucent and bluish rendering them, also, seen with difficulty.

Experiment II.

BILE SALT MEDIUM.

In water analysis, a bile salt medium is often used for differentiating *B. typhosus* and *B. coli*. McConkey[8] states that "Bile salt media inhibit most of the organisms found in air and soil when the incubation temperature is 37°C. and over." He uses lactose in combination with the bile salt to assist in the differentiation.

Relying on the efficiency of this medium for differentiating *B. typhosus* from air, soil, and other microörganisms, and working under the supposition that lactic bacteria would respond in much the same manner as

the classes of bacteria mentioned, a bile medium was prepared and tested for trial by plating pure cultures of typhoid and lactic bacteria.

Preparation of the Bile Medium.—Owing to the fact that no form of bile salts, sodium taurocholate or glycocholate, were available at this time, bile from a freshly slaughtered ox and sheep was substituted. The agar was made in two lots, using the bile of the ox for one lot and that of the sheep for the other.

This medium was prepared as follows: 15 g. of agar was soaked in 500 cc. water over night. In the morning 20 g. peptone and 5 g. salt were dissolved in 100 cc. hot water and added to the agar, which had been digested previously. 20 g. lactose dissolved in 400 cc. hot water was added next. This was divided into equal parts (500 cc. each); to one was added the bile* of the sheep, to the other the ox bile* (about 30 cc. each).

Just before filtering, 1 per cent of a standard solution of Merck's purified litmus[7] was added to each lot of agar.

Broth cultures of the *Bact. lactis acidi* (lab.) and *B. typhosus* respectively were plated on each lot of the litmus lactose bile agar to test its efficiency. The respective colonies could be distinguished readily from one another. The presence of the bile in the medium seemed to inhibit the growth of the lactic organism almost entirely.

Two or three lactic colonies developed upon the ox-bile agar, none upon the sheep-bile agar. The lactic colonies upon the ox-bile agar were very small, round and transparent, resembling a minute drop of water. For positive identification several of these colonies were transferred to broth, incubated until signs of growth were shown and then transferred to litmus milk tubes. The typical lactic reaction took place within 24 hours.

The typhoid bacilli grew well upon both lots of this agar; both the surface and sub-surface colonies were easy to differentiate from those of the lactic.

This differentiation being quite satisfactory, the same experiment was continued, making duplicate plates in ox-bile agar and in "calcium-carbonate" agar. The counts for *Bact. lactis acidi* (lab.) were taken from the calcium-carbonate agar and for *B. typhosus* from the bile agar.

*The gall bladders were obtained from a freshly slaughtered carcass of a sheep and an ox and were brought to the laboratory under sterile precautions, broken separately into sterile deep culture dishes, and placed in cold storage until used.

TABLE II.—*Summary of Tests VII-XII Inclusive.*
DIFFERENTIAL COUNTS ON OX-BILE AND CALCIUM-CARBONATE AGAR RESPECTIVELY.

Number of test.	Age of combined culture.	Acidity of culture at time of estimate.	Number of bacteria in each cubic centimeter of milk at the times specified.	
			B. typhosus.	*Bact. lactis acidi (lab.)*
VII	0 hours	15°	2,034,575	268,293
	22 hours	73°	119,000,000	290,000,000
	76.5 hours	82°	11,000,000	Counts lost.
VIII	0 hours	15°	1,898,000	1,580,000
	23 hours	62°	24,467,000	352,000,000
	46.5 hours	68°	None.	424,000,000
IX	0 hours	15°	5,025,000	3,550,000
	21 hours	61°	107,000,000	229,800,000
	47 hours	70°	None.	300,000,000
X	0 hours	15°	1,775,000	1,675,000
	23 hours	68°	35,200,000	334,100,000
	46 hours	80°	650,000	97,000,000
XI	0 hours	15°	2,385,000	1,426,250
	39 hours	71°	6,500,000	118,000,000
XII	0 hours	15°	2,215,000	1,677,500
	26 hours	64°	5,400,000	115,000,000

From the above table, it will be noted that the lactic acid produced by *Bact. lactis acidi* (lab.) becomes inhibitive to *B typhosus* from 24-48 hours after inoculation when the acidity at that time has reached 68°-80° or over.

It will be noted also, in this table, that a higher degree of acidity and a longer time exists before the inhibitive effect takes place than in the previous table. This is easily accounted for by the fact that more accurate results were obtained by use of the check plates.

Tests I-XII were carried on with *Bact. lactis acidi* (lab.). As we were desirous of obtaining other types of lactic organisms for comparison with the one used in the above experiments, through the courtesy of Dr. Heinemann and Dr. Hefferan of the University of Chicago, we were furnished with several cultures of lactics.

The following are the names of the lactic organisms used in the succeeding experiments:

Bact. acidi lactici, Hueppe.
Bact. acidi lactici, Novy.
Bact. acidi lactici No. 1.
Bact. acidi lactici No. 2.
Strept. lacticus.

At this time, several different lactic cultures were received from Dr. Harding of the New York Experiment Station at Geneva. Only one was used in the following experiments, *Bact. lactis acidi,* Harding.

As the supply of ox-bile agar was exhausted at this time, the third lot of experiments was carried on with sheep-bile agar.

It will be noted also that the number of typhoid and of lactic microorganisms on each medium is recorded.

At this point, it might be well to note some of the characteristics of the lactic organisms used in the following experiments. *Bact. acidi lactici*, Hueppe, *Bact. acidi lactici*, Novy, *Bact. acidi lactici*, No. 1, and *Bact. acidi lactici*, No. 2, produced gas and an offensive odor in ordinary broth; no gas or odor was produced by *Strept. lacticus* and *Bact. lactis acidi*, Harding. All the above microörganisms produced acid in litmus milk and eventually curded it, taking from three to eight days for this to be accomplished. The first four lactics mentioned, grew abundantly on agar; *Bact. acidi lactici*, Novy, and *Bact. acidi lactici*, No. 1 were motile.

TABLE III.—*Differential Counts on Sheep-Bile and Calcium-Carbonate Agar Using Different Lactic Bacteria.*

O. A. = ORDINARY AGAR; S. B. A. = SHEEP-BILE AGAR; C. C. A. = CALCIUM-CARBONATE AGAR.

No. of test.	Age of combined culture.	Acidity of culture at time of estimate.	Medium.	Number of bacteria in each cubic centimeter of milk at the times specified.		
				B. typhosus.	Lactic organisms.	
					Count.	Designation.
XIII	0 hours	15°	O. A.	5,175,000	2,523,750	*Bact. acidi lactici*, No. 2.
	23 hours	64°	S. B. A.	600,000	No record	
			C. C. A.	8,500,000	583,300,000	
XIV	0 hours	15°	O. A.	5,175,000	1,058,750	*Strept. lacticus.*
	23 hours	66°	S. B. A.	None.	1,706,500,000	
			C. C. A.	None.	465,830,000	
XV	0 hours	15°	O. A.	4,675,000	1,103,750	*Bact. lactis acidi*, Harding.
	23 hours	63°	S. B. A.	100,000	1,400,000	
			C. C. A.	6,000,000	253,670,000	
XVI	0 hours	15°	O. A.	3,231,250	275,000	*Strept. lacticus.*
	23.5 hours	61°	S. B. A.	19,230,000	559,330,000	
			C. C. A.	None.	558,500,000	
XVII	0 hours	15°	O. A.	1,456,250	1,800,000	*Bact. acidi lactici*, Hueppe.
	50.5 hours	64°	S. B. A.	26,867,000	....	
			C. C. A.	....	34,500,000	
XVIII	0 hours	15°	O. A.	2,043,750	1,425,000	*Bact. acidi lactici*, Novy.
	23.5 hours	50°	S. B. A.	9,500,000	410,000,000	
			C. C. A.	57,000,000	227,000,000	
XIX	0 hours	15°	O. A.	2,043,750	2,280,000	*Bact. acidi lactici*, No. 1.
	24 hours	50°	S. B. A.	38,500,000	324,000,000	
			C. C. A.	40,000,000	90,000,000	
	91 hours	63°	S. B. A.	None.	None.	
			C. C. A.	None.	None.	
XX	0 hours	15°	O. A.	2,043,750	2,715,000	*Bact. acidi lactici*, No. 2.
	16 hours	64°	S. B. A.	85,500,000	602,500,000	
			C. C. A.	86,000,000	450,000,000	
	91 hours	67°	S. B. A.	None.	None.	
			C. C. A.	None.	None.	

All of the lactic bacteria in Table III grew vigorously on the litmus lactose bile agar, some producing so much acid that the typhoid colonies were colored red also.

In every case, higher counts for *B. typhosus* were obtained on the calcium-carbonate agar than upon the bile agar and in nearly every case greater numbers of lactics were found upon the sheep-bile agar, which results are the reverse of those summarized in Table II.

This bile agar did not prove to be a successful differentiating medium for any of the lactic organisms except *Bact. lactis acidi* (lab.).

In only two tests in Table III was the purpose of these tests accomplished, Nos. XIX and XX, in which the typhoid germs (also the lactic) were killed somewhere within 91 hours at 63°-67° acid.

These results, however, were utilized later, in further experiments.

A summary of Tables I, II, and III, with regard to the decrease in the typhoid content is found in Table IV; with regard to the total destruction of the typhoid bacteria, in Table V.

TABLE IV.—*Decrease in Typhoid Content.*

Number of test.	Time after inoculation.	Acidity of milk at the time specified.
II	16 ½ hours	49°
III	22 ¼ hours	66°
IV	22 ¾ hours	60°
VII	76 ½ hours	82°
X	46 hours	80°

The typhoid bacilli were all killed in the experiments noted in the following table:

TABLE V.—*Total Destruction of Typhoid Bacteria.*

Number of test.	Time after inoculation.	Acidity of milk at the time specified.
III	40½ hours	73°
V	43 hours	75°
VI	23½ hours	79°
VIII	46½ hours	68°
IX	47 hours	70°
XIV	23 hours	66°
XIX	91 hours	63°
XX	91 hours	67°

The time element in the foregoing tests seems the most pertinent in comparison with the total extermination of the typhoid bacteria in the milk. In only two tests, Nos. VI and XIV, are the typhoid bacilli killed within 24 hours. In test No. III, there is a possibility of their having been killed in 22¼ hours; in test No. V, the milk was not plated until 43 hours had elapsed; in test No. VII, the acidity had not risen high enough at the end of 23 hours to kill the typhoid organisms; it probably rose in a short time from 62° to 68°, but was not plated until 46½ hours had elapsed; all the typhoid bacilli were probably killed a few hours after the milk reached 68° acid. In the ninth test, practically the same conditions existed as in the preceding one.

Experiment III.

FILTRATION EXPERIMENTS.

The unsatisfactory results furnished under Experiments I and II seem to demand a complete change of methods. The main difficulty heretofore, has been that of successfully differentiating the typhoid and lactic bacteria by the use of a special medium for plating. To obviate this difficulty, the plan was formulated of growing *B. typhosus* in the products only, of the lactic organisms. The hypothesis is, the products of the lactic bacteria and not the bacteria themselves exert a deleterious influence upon the typhoid bacteria.

The most feasible way of carrying out this plan appears to be that of growing the lactic organisms in a suitable medium from which they could be easily filtered; the filtrate would thus contain their products in solution and, when properly controlled would be wholly free from organisms. The typhoid bacteria could then be introduced into this germ-free filtrate and plates made at any time in ordinary agar, thus making the use of a differential medium unnecessary.

By a preliminary test, lactose broth was found to be the medium which would best lend itself to the abundant growth of the lactic organisms and permit of filtration of the cultures.

Medium.—This broth was made by adding 1½ per cent lactose and 1 per cent peptone to the meat infusion. The first lot of broth was made +10°, the second +15°, nearer perhaps the average acidity of milk. The broth was then placed in 375 cc. Erlenmeyer flasks and sterilized.

Apparatus.—The broth cultures of the lactic organisms were filtered through a Pasteur-Chamberland "F" bougie used in connection with Novy's filtering apparatus; Reichel's filtering apparatus was also used in one or two trials.

The lactic organisms used in this series of experiments were *Strept. lacticus*, *Bact. lactis acidi* (lab.), *Bact. lactis acidi* No. 226, *Bact. lactis acidi*, Harding, *Bact. acidi lactici* "Lactone," *Bact. lactis acidi* (stock), and *Bact. acidi lactici* No. 2, and in addition, three new cultures received, in the meantime, from the Geneva Experiment Station, *Bact. lactis acidi* (from cheese), *Bact. lactis acidi* (from whey), and *Bact. lactis acidi* (from starter).

Methods.—Two or three hundred cubic centimeters of lactose broth were inoculated with a known lactic organism and incubated at 37°C. The acidity of the culture was determined from time to time by titrating with N/20 NaOH. Each sample was boiled before titrating to expel volatile acids. The exact time of titration and the degree of acidity were recorded each time.

When the maximum acidity had developed, the culture was allowed to remain at least 24 hours longer at 37°C. then filtered into a sterile flask (the bougie and flask had been autoclaved 10 minutes at 121°C.).

When from 150 to 200 cc. of the broth culture had been filtered, two flasks of sterile lactose broth (50 cc.) were inoculated with 5 cc. of the filtrate and together with the filtrate, incubated at 37°C.* If no growth occurred in any of the flasks, a known number of typhoid organisms was

*The check flasks were inoculated with the filtrate to allow the lactic organisms to develop if they passed the filter. They would probably not have been able to grow in the filtrate containing an excess of their own products.

introduced into the filtrate which was again incubated at the above temperature.

The number of typhoid bacilli introduced into each cc. of the filtrate was determined as follows: A small portion of an 18-24 hour broth culture of *B. typhosus* was introduced into the filtrate by means of a sterile pipette. Three agar plates were then made, using 1 cc., 0.5 cc. and 0.1 cc., respectively of the inoculated filtrate, and the average count taken after a sufficient period of incubation. After 24 hours a second set of plates was made using the same dilutions as before. If the filtrate had become turbid, dilutions of 1-1,000,000, 1-5,000,000 and 1-10,000,000 were used for plating.

If the second plating showed the presence of typhoid bacteria in the filtrate, a third set of plates was made, etc.

TABLE VI.—*Strept. lacticus.*

Number of test.	Age of lactic culture.	Acidity of lactic cultures.	Filt'd	Number of typhoid bacilli per cc. of filtrate.		
				Introduced.	Hours after inoculation.	Count.
I	0 hours 72 hours	10° 70°	+	Discarded check flask contained *Strept. lacticus.*		
II	0 hours 72 hours 12 days	10° 58° 58°	+	Discarded check flask contained *Strept. lacticus.*		
III	0 hours 60 hours 130 hours 203 hours 253 hours	10° 54° 60° 63° 64°	+	191,700	19 hours	None.
IV	0 hours 72 hours 120 hours	10° 68° 68°	+	58,650	22.5 hours	None.
V	0 hours 28.5 hours 49 hours 100.5 hours	15° 60° 60° 60°	+	106,000	22.5 hours 45 hours	None. None.
VI	0 hours 28.5 hours 49 hours 100.5 hours	15° 60° 61° 61°	+	198,450	26.5 hours	None.
VII	0 hours 28.5 hours 49 hours 100.5 hours	15° 61° 61° 61°	+	247,000	26.5 hours	None.

TABLE VII.—*Bact. lactis acidi* (*lab*).

Number of test.	Age of lactic culture.	Acidity of lactic cultures.	Filt'd	Number of typhoid bacilli per cc. of filtrate.		
				Introduced.	Hours after inoculation.	Count.
I	0 hours 168 hours	10° 34°	+	Discarded.		
II	0 hours 600 hours	10° 42°	+	59,550	26 hours 53 hours	None None.
III	0 hours 120 hours 190 hours	10° 32° 32°	+	82,830	24 hours Not plated.	183,000,000

TABLE VIII.—*Bact. lactis acidi* (*from cheese*).

Number of test.	Age of lactic culture.	Acidity of lactic cultures.	Filt'd	Number of typhoid bacilli per cc. of filtrate.		
				Introduced.	Hours after inoculation.	Count.
I	0 hours 240 hours	10° 50°	+	57,340	26 hours Not plated.	9
II	0 hours 120 hours 192 hours	10° 41° 41°	+	156,000	24 hours Not plated.	1,310,000
III	0 hours 72 hours 168 hours	10° 48° 48°	+	136,700	25 hours 48 hours	None. None.

TABLE IX.—*Bact. lactis acidi, No. 226.*

Number of test.	Age of lactic culture.	Acidity of lactic cultures.	Filt'd	Number of typhoid bacilli per cc. of filtrate.		
				Introduced.	Hours after inoculation.	Count.
I	0 hours 120 hours 192 hours 291 hours 339 hours	10° 18° 34° 41° 45°	+	64,800	25.5 hours Not plated.	197,700,000

TABLE X.—*Bact. lactis acidi, Harding.*

Number of test.	Age of lactic culture.	Acidity of lactic cultures.	Filt'd	Number of typhoid bacilli per cc. of filtrate. Introduced.	Hours after inoculation.	Count.
I	0 hours	10°	+	106,780	26 hours	23?
	216 hours	42°			53 hours	None.
	528 hours	45°				
II	0 hours	10°	+	88,920	30.5 hours	None.
	125 hours	50°			53.3 hours	None.
	192 hours	54°				
	288 hours	54°				
III	0 hours	10°	+	79,290	29.5 hours	None.
	72 hours	60°			54.5 hours	None.
	168 hours	60°				
IV	0 hours	15°	+	58,950	23.5 hours	None.
	28.5 hours	62°			47.5 hours	None.
	49.5 hours	62°				
	100.5 hours	62°				
V	0 hours	15°	+	9,960	24 hours	2
	28.5 hours	60°			46.5 hours	None.
	49.5 hours	60°				
	100.5 hours	60°				

TABLE XI.—*Bact. acidi lactici, "Lactone."*

Number of test.	Age of lactic culture.	Acidity of lactic cultures.	Filt'd	Number of typhoid bacilli per cc. of filtrate. Introduced.	Hours after inoculation.	Count.
I	0 hours	10°	+	178,650	29.5 hours	540,000
	120 hours	36°			Not plated.	
	192 hours	40°				
	288 hours	40°				

TABLE XII.—*Bact. lactici acidi (from whey).*

Number of test.	Age of lactic culture.	Acidity of lactic cultures.	Filt'd	Number of typhoid bacilli per cc. of filtrate. Introduced.	Hours after inoculation.	Count.
I	0 hours	10°	+	57,000	22.5 hours	11,610
	96 hours	40°			51 hours	*11,780
	166 hours	45°				
	264.5 hours	48°				
	315 hours	48°				
II	0 hours	10°	+	139,500	19 hours	38,700,000
	96.5 hours	34°			Not plated.	
	166 hours	36°				
	264.5 hours	40°				
	315 hours	40°				
III	0 hours	10°	+	209,250	22.5 hours	Uncountable.
	66.5 hours	42°			Not plated.	
	164.5 hours	47°				
	215 hours	47°				

*See note under Table XVII.

TABLE XIII.—*Bact. lactis acidi, (stock).*

Number of test.	Age of lactic culture.	Acidity of lactic cultures.	Filt'd	Number of typhoid bacilli per cc. of filtrate.		
				Introduced.	Hours after inoculation.	Count.
I	0 hours 96 hours 168 hours 264 hours 312 hours	10° 61° 62° 67° 67°	+	221,500	25 hours Not plated.	None.
II	0 hours 96 hours 166.5 hours 265 hours 315 hours	10° 52° 55° 61° 61°	+	43,650	25.5 hours 49 hours	None. None.
III	0 hours 68 hours 167 hours 316 hours	10° 64° 67° 67°	+	2,390	25.5 hours Not plated.	None.
IV	0 hours 19 hours 48.5 hours 70.5 hours 93 hours	15° 25° 55° 61° 61°	+	74,250	22.5 hours 49 hours	None. None.
V	0 hours 29.5 hours 51.5 hours 74 hours	15° 57° 61° 61°	+	47,700	22.5 hours 49 hours	None. None.

TABLE XIV.—*Bact. lactis acidi (from starter).*

Number of test.	Age of lactic culture.	Acidity of lactic cultures.	Filt'd	Number of typhoid bacilli per cc. of filtrate.		
				Introduced.	Hours after inoculation.	Count.
I	0 hours 96 hours 167 hours 290 hours 339 hours	10° 52° 56° 59° 59°	+	69,300	22.5 hours Not plated.	4
II	0 hours 72 hours 168 hours 288 hours	10° 56° 61° 61°	+	108,900	29.5 hours 54.5 hours	None. None.
III	0 hours 68 hours 167 hours 316 hours	10° 63° 65° 65°	+	37,350	22.5 hours Not plated.	None.
IV	0 hours 75.5 hours 123.5 hours	10° 66° 66°	+	8,240	25.5 hours Not plated.	None.
V	0 hours 28.5 hours 49.5 hours 101 hours	15° 59° 61° 61°	+	33,700	24 hours Not plated.	None.

TABLE XV.—*Bact. acidi lactici, No. 2.*

Number of test.	Age of lactic culture.	Acidity of lactic cultures.	Filt'd	Number of typhoid bacilli per cc. of filtrate.		
				Introduced.	Hours after inoculation.	Count.
I	0 hours 96 hours 168 hours	10° 48° 48°	+	155,700	24 hours 49 hours	12,170 None.
II	0 hours 68 hours 167 hours 316 hours	10° 53° 58° 58°	+	212,400	19 hours 44.5 hours	50 None.
III	0 hours 74.5 hours 123.5 hours	10° 54° 54°	+	102,150	19 hours 44.5 hours	175 None
IV	0 hours 28.5 hours 49.5 hours 79 hours 101 hours	15° 40° 46° 46° 46°	+	72,000	24 hours 46.5 hours	186 None.
V	0 hours 28.5 hours 49.5 hours 79 hours 101 hours	15° 41° 44° 46° 46°	+	87,750	24 hours Not plated.	None.

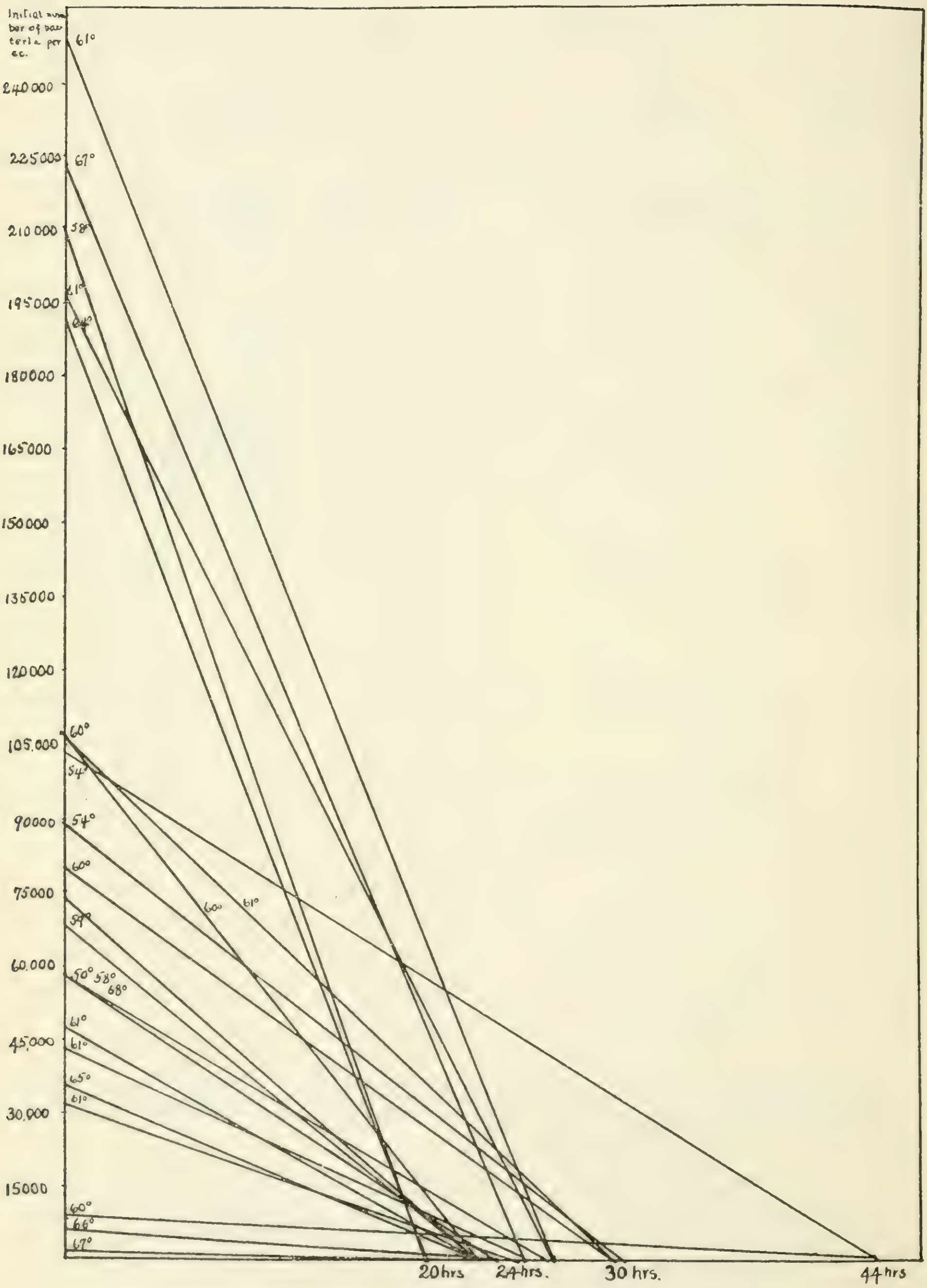
The following table is a summary of Tables VI to XV. The experiments are arranged according to the degree of acidity produced by the lactic organisms.

TABLE XVI.

Acidity of broth.	No. of test.	Lactic organism.	Number of typhoid bacilli per cc. of filtrate. Introduced.	No. at 2nd plating.	No. at 3rd plating.	Remarks.
32°	III	*Bact. lactis acidi* (lab.)	82,830	183,000,000	Not plated	Increased in 24 hours.
40°	II	*Bact. lactis acidi* (from whey)	139,500	38,700,000	Not plated	Increased in 19 hours.
	I	*Bact. acidi lactici* "Lactone"	178,650	540,000	Not plated	Increased in 29. 5 hours.
41°	II	*Bact. lactis acidi* (from cheese)	156,000	1,310,000	Not plated	Increased in 24 hours.
42°	II	*Bact. lactis acidi* (lab.)	59,550	None	None	Killed within 26 hours.
45°	I	*Bact. lactis acidi*, Harding	106,780	232	None	Killed within 53 hours.
	I	*Bact. lactis acidi*, No. 226	64,800	197,700,000	Not plated	Increased in 25. 5 hours.
46°	IV	*Bact. acidi lactici*, No. 2	72,000	186	None	Killed within 46.5 hours.
	V	*Bact. acidi lactici*, No. 2	87,750	None	Not plated	Killed within 24 hours.
47°	III	*Bact. lactis acidi* (from whey)	209,250	Uncountable.	Not plated	Increased in 22.5 hours.
48°	III	*Bact. lactis acidi* (from cheese)	136,700	None	None	Killed within 25 hours.
	I	*Bact. lactis acidi* (from whey)	57,000	11,610	11,780	See note*
	I	*Bact. acidi lactici*, No. 2	155,700	12,170	None	Killed within 49 hours.
50°	I	*Bact. lactis acidi* (from cheese)	57,340	9	Not plated	Decreased in 26 hours.
54°	II	*Bact. lactis acidi*, Harding	88,920	None	None	Killed within 30.5 hours.
	III	*Bact. acidi lactici*, No. 2	102,150	175	None	Killed within 44.5 hours.
58°	II	*Bact. acidi lactici*, No. 2	212,400	50	None	Decreased in 19 hours.
59°	I	*Bact. lactis acidi* (from starter)	69,300	4	Not plated	Decreased in 22.5 hours.
60°	V	*Strept. lacticus*	106,000	None	None	Killed within 22.5 hours.
	III	*Bact. lactis acidi*, Harding	79,290	None	None	Killed within 29.5 hours.
	V	*Bact. lactis acidi*, Harding	9,960	2	None	Killed within 46.5 hours.
61°	VI	*Strept. lacticus*	198,450	None	Not plated	Killed within 26.5 hours.
	VII	*Strept. lacticus*	247,000	None	Not plated	Killed within 26.5 hours.
	II	*Bact. lactis acidi* (stock)	43,650	None	None	Killed within 25.5 hours.
	V	*Bact. lactis acidi* (stock)	47,700	None	None	Killed within 22.5 hours.
	IV	*Bact. lactis acidi* (stock)	74,250	None	None	Killed within 22.5 hours.
	II	*Bact. lactis acidi* (from starter)	108,900	None	None	Killed within 29.5 hours.
	V	*Bact. lactis acidi* (from starter)	33,700	None	Not plated	Killed within 24 hours.
62°	IV	*Bact. lactis acidi*, Harding	58,950	None	None	Killed within 23.5 hours.
64°	III	*Strept. lacticus*	191,700	None	Not plated	Killed within 19 hours.
65°	III	*Bact. lactis acidi* (from starter)	37,350	None	Not plated	Killed within 22.5 hours.
66°	IV	*Bact. lactis acidi* (from starter)	8,240	None	Not plated	Killed within 25.5 hours.
67°	I	*Bact. lactis acidi* (stock)	221,500	None	Not plated	Killed within 25 hours.
	III	*Bact. lactis acidi* (stock)	2,390	None	Not plated	Killed within 25.5 hours.
68°	IV	*Strept. lacticus*	58,650	None	Not plated	Killed within 22.5 hours.

*A fourth plating after incubation for 70 hours at 37°C. gave 14,700 colonies per cc. After further incubation ($95\frac{1}{2}$ hours) the broth had become turbid and dilution plates on litmus lactose agar showed approximately 24,700,000 red colonies and 8,700,000 blue colonies per cc. of filtrate. A few drops of the turbid broth introduced into sterile litmus milk and kept at 37° produced acid in 24 hours and eventually curded the milk.

From 50° acidity up to 68°, the lactic acid produced by several lactics, *Bact. lactis acidi* (from cheese), *Bact. lactis acidi*, Harding, *Bact. acidi lactici*, No. 2, *Bact. lactis acidi* (from starter), *Strept. lacticus*, and *Bact. lactis acidi* (stock) is strongly inhibitive to the typhoid organisms; this is graphically illustrated in the following chart:


Initial number of bacteria per cc.
240000
225000
210000
195000
180000
165000
150000
135000
120000
105,000
90000
75000
60,000
45,000
30,000
15000
61°
67°
58°
61°
64°
60°
54°
54°
60°
59°
50°
58°
68°
61°
61°
65°
61°
60°
66°
67°
60°
61°
20 hrs
24 hrs.
30 hrs.
44 hrs

CURVE 1.

As seen by Table XVI, the same amount of acid as produced by different lactic organisms has a different effect on the longevity of the typhoid bacillus (see especially 45° and 48° acid). Whether this is due to the natural variation which takes place in different cultures of the same organism (see 46° and 60° acid) or whether it is due to the difference in the by-products other than lactic acid, of the different lactic organisms, is still a matter of question.

However, a certain uniformity in the inhibitive effect of the fermentation lactic acid is shown by Table XVI. From 60°-68° acid, the products of four different lactic organisms kill the typhoid bacteria within from 19 to 30 hours, i. e., within 24 hours on the average.

TABLE XVII.

Lactic organism.	No. of test.	Acidity of lactic culture.	Number of typhoid bacilli per cc. of filtrate.			
			Introduced.	2nd plating.	3rd plating.	Remarks.
Bact. acidi lactici "Lactone"	I	40°	178,650	540,000	Not plated	Increased in 29 hours.
Bact. lactis acidi (lab.)	III	32°	82,830	183,000,000	Not plated	Increased within 24 hours.
	II	42°	59,550	None	None	Killed within 26 hours.
Bact. lactis acidi (from whey)	II	40°	139,500	38,700,000	Not plated	Increased within 19 hours.
	III	47°	209,250	Uncountable	Not plated	Increased within 22.5 hrs.
	I	48°	57,000	11,610	11,780	See note *under Table XVI
Bact. lactis acidi (from cheese)	II	41°	156,000	1,310,000	Not plated	Increased within 24 hours.
	III	48°	136,700	None	None	Killed within 25 hours.
	I	50°	57,340	9	Not plated	Decreased within 26 hours.
Bact. lactis acidi, Harding	I	45°	106,780	23?	None	Killed within 53 hours.
	II	54°	88,920	None	None	Killed within 30.5 hours.
	III	60°	79,290	None	None	Killed within 29.5 hours.
	V	60°	9,960	2	None	Killed within 46 5 hours.
	IV	62°	58,950	None	None	Killed within 23.5 hours.
Bact. acidi lactici, No. 2	IV	46°	72,000	186	None	Killed within 46.5 hours.
	V	46°	87,750	None	Not plated	Killed within 24 hours.
	I	48°	155,700	12,170	None	Killed within 49 hours.
	III	54°	102,150	175	None	Killed within 44.5 hours.
	II	58°	212,400	50	None	Decreased within 19 hours.
Bact. lactis acidi (from starter)	I	59°	61,300	4	Not plated	Decreased within 22.5 hrs.
	II	61°	108,900	None	None	Killed within 29.5 hours.
	V	61°	33,700	None	Not plated	Killed within 24 hours.
	III	65°	37,350	None	Not plated	Killed within 22.5 hours.
	IV	66°	8,240	None	Not plated	Killed within 25.5 hours.
Strept. lacticus	V	60°	106,000	None	None	Killed within 22.5 hours.
	VI	61°	198,450	None	Not plated	Killed within 26.5 hours.
	VII	61°	247,000	None	Not plated	Killed within 26.5 hours.
	III	64°	191,700	None	Not plated	Killed within 19 hours.
	IV	68°	58,650	None	Not plated	Killed within 22.5 hours.
Bact. lactis acidi (stock)	II	61°	43,650	None	None	Killed within 25.5 hours.
	V	61°	47,700	None	None	Killed within 22.5 hours.
	VI	61°	74,250	None	None	Killed within 22.5 hours.
	I	67°	221,500	None	Not plated	Killed within 25 hours.
	III	67°	2,390	None	Not plated	Killed within 25.5 hours.

Table XVII is practically the same as Table XVI. It is arranged, however, to show:

1. The relative inhibitive power of the different lactic organisms used;
2. The relative inhibitive power of the different maximum acidities produced in lactose broth by one lactic organism.

The use of *Bact. acidi lactici* "Lactone" was discontinued after the first test as it repeatedly failed to make more than 40° acid in subsequent inoculations into lactose broth.

The use of *Bact. lactis acidi* (lab.) was discontinued for the same reason and although *Bact. lactis acidi* (from whey) produced considerably more acid than *Bact. acidi lactici* "Lactone" or *Bact. lactis acidi* (lab.), its inhibitive power was very weak and consequently it also was discarded.

Bact. lactis acidi (from cheese), *Bact. lactis acidi*, Harding, and *Bact. acidi lactici*, No. 2 illustrate the minimum acidity which destroys typhoid bacteria, which is about 45°-46°, or 0.4 per cent lactic acid. This destruction takes place in from 24 to 53 hours according to the above tables.

Observations.—The maximum acidity produced in lactose broth by one lactic microörganism varies with each inoculation. To illustrate this, the following table has been compiled from Table XVII.

TABLE XVIII.

Lactic organism.	Number of inoculations.	Acidity in degrees. Minimum.	Maximum.	Degrees of variation.
Bact. lactis acidi (lab.)	2	32°	42°	10°
Bact. lactis acidi (from whey)	3	40°	48°	8°
Bact. lactis acidi (from cheese)	3	41°	50°	9°
Bact. lactis acidi, Harding	5	45°	62°	17°
Bact. acidi lactici, No. 2	5	46°	58°	12°
Bact. lactis acidi (from starter)	5	59°	66°	17°
Strept. lacticus	5	60°	68°	8°
Bact. lactis acidi (stock)	5	61°	67°	6°

As a rule, the initial number of typhoid organisms present in the broth, whether large or comparatively few, does not influence the number found at the second plating, whatever the acidity of the broth; e. g., at 46° acid, the broth flask containing the fewer *Bact. acidi lactici* No. 2 still contains an appreciable number at the second plating (24 hrs. after inoculation), while the other flask having the greater initial number, contains none. (See Table XV). This also illustrated at 40° and 48° acid and in a different way at 45° acid, (see Table XVI), shows the comparative germicidal properties exercised by different organisms. If lactose broth contains 50° acid or more, a steady and rapid decrease

in the number of organisms introduced takes place, seemingly irrespective of the greater or lesser initial number.

Experiment IV.

Further experiments in the filtration of the lactose broth cultures of different lactic organisms were carried on for the comparison of the acid produced by each with regard to their relative germicidal powers. Owing to the length of time which elapsed between the inoculation of the filtrate with *B. typhosus* and the second and third platings, the time in which the destruction of the typhoid bacteria took place was not sufficiently defined. This was remedied by plating at 7, 24, 31, 48, etc., hours after inoculation.

Organisms.—The lactic organism, *Bact. lactis acidi* (from starter) is now a weak lactic, while *Bact. lactis acidi* (from sour milk) represents the typical lactic; *Bact. acidi lactici*, No. 2 produces acid and gas in broth also in milk; *Bact. lactis acidi*, 53 B2 is a lactic acid-producing organism isolated from a sample of milk which contained nearly 2 per cent lactic acid; it also possesses the power at times of producing slimy milk; *Bact. bulgaricum* was isolated from a culture of Yoghourt imported from Holland.

These microörganisms were taken as a fair representation of the most common diverse types of lactic organisms.

The outline for this experiment differs somewhat from that in the previous filtration experiment.

Medium.—In the first two or three tests 1½ per cent lactose broth (+18°) was used; broth (+15°) containing 5 per cent lactose was used for the concluding tests as being nearer the lactose content of milk.

Method.—About 200 cc. lactose broth (+18°) was inoculated with the lactic culture and incubated at room temperature (21°-25°C.). The acidity was tested from time to time, and when the culture had reached 40° acid or thereabouts, it was immediately filtered. The filtrate was separated into two parts by means of a sterile pipette, and transferred into sterile flasks, every precaution being taken to keep it from being contaminated.

Both flasks were incubated at 37°C. for 48 hours to give any organisms present a chance to assert themselves.*

If no growth occurred in either flask, one was inoculated with a known number of typhoid germs, the second flask being sealed and kept for control.

The time for plating was kept as nearly constant as possible, the time being, 7, 24, 31, 48 hours, etc., after inoculation of the filtrate. Plating was continued as long as the filtrate remained clear or until the typhoid bacilli were all destroyed.

The plates were kept at 37°C. for 24 hours, then at room temperature for 48 hours before the final count was taken.

*Check flasks (as in note, p. 489) were not necessary as the lactic organisms were not allowed to produce enough of their own products (i. e., their maximum acid) to inhibit any organisms which might pass through the filter.

TABLE XIX.—*Bact. lactis acidi* (*from starter*).

GROWN IN 1½ PER CENT LACTOSE BROTH.

Number of test.	Age of lactic culture.	Acidity of lactic culture.	Number of typhoid bacilli per cc. in filtrate.	
			Age of culture.	Count.
VI	26.5 hours	16°	Introduced	1,422
	31.5 hours	20°	7 hours	883
	47 hours	17°	24 hours	287
	54.5 hours	22°	31 hours	220
	71 hours	21°	48 hours	†60
	98 hours	26°	72 hours	†6
	119 hours	29°	81 hours	†None.
			120 hours	10
			127 hours	None.
			144 hours	†2
			151 hours	2
			168 hours	1
			192 hours	None.
			216 hours	None.
			240 hours	1?
			268 hours	None.
			288 hours	1
VII	23.5 hours	18°	Introduced	19,860
	46 hours	22°	7 hours	37,935
	71 hours	21°	24 hours	Uncountable.
	95 hours	22°	31 hours	Uncountable.
	144.5 hours	23°	48 hours	Broth turbid.
	166 hours	24°		
VIII*	21.5 hours	28°	Introduced	5,626
	47.5 hours	28°	7 hours	5,168
	70 hours	29°	24 hours	5,158
			31 hours	5,106
			48 hours	9,198
			56 hours	16,680
			72 hours	96,030
			99 hours	Uncountable.

*Five per cent lactose broth used in the eighth trial.
†Plates so contaminated that an accurate count could not be made.

TABLE XX.—*Bact. acidi lactici, No. 2.*

GROWN IN 1½ PER CENT LACTOSE BROTH.

Number of test.	Age of lactic culture.	Acidity of lactic culture.	Number of typhoid bacilli per cc. in filtrate.	
			Age of culture.	Count.
VI	71 hours	28°	Introduced	7,768
			7 hours	4,626
			24 hours	5,463
			31 hours	5,850
			48 hours	5,060
			55 hours	4,893
			72 hours	5,330
			79 hours	†2,100
			96 hours	4,165
			120 hours	†2,926
			129 hours	†2,435
			216 hours	5,786
			264 hours	Broth turbid.
VII*	21 hours	27°	Introduced	2,413
	47.5 hours	32°	7 hours	887
	70.5 hours	32°	24 hours	771
	94 hours	30°	32 hours	627
			48 hours	456
			75 hours	84
			96 hours	27
			103 hours	3
			120 hours	2
			144 hours	None.
VIII*	23 hours	34°	Introduced	21,510
	28 hours	33°	23 hours	13,643
	48 hours	34°	30 hours	17,750
			47 hours	39,870
			54 hours	51,795
			71 hours	38,475
			78 hours	42,615
			95 hours	37,885
			103 hours	49,080
			119 hours	59,220
			126 hours	58,050
			143 hours	65,500
			168 hours	Contaminated with molds.

*Grown in 5 per cent lactose broth.
†See note † under Table XIX.

TABLE XXI.—*Bact. lactis acidi, 53 B2.*

GROWN IN 1½ PER CENT LACTOSE BROTH.

Number of test.	Age of lactic culture.	Acidity of lactic culture.	Number of typhoid bacilli per cc. in filtrate.	
			Age of culture.	Count.
I	39.5 hours	21°	Introduced	11,106
	47.5 hours	28°	7 hours	9,118
			24 hours	Broth turbid.
II	112 hours	56°	Introduced	1,253
			7 hours	1,762
			24 hours	1,400
			32 hours	1,596
			48 hours	1,368
			55 hours	1,145
			76 hours	1,393
			96 hours	2,088
			103 hours	4,475
			120 hours	36,090
			127 hours	63,945
			144 hours	75,060
			151 hours	105,390
			168 hours	Uncountable.
III	23 hours	19°	Introduced	7,700
	46 hours	30°	7 hours	None.
	62 hours	44°	24 hours	None.
	78 hours	58°	31 hours	None.
	99.5 hours	68°	48 hours	None.
IV*	21 hours	22°	Introduced	381
	47.5 hours	49°	2 hours	None.
	70.5 hours	59°	4 hours	None.
	94 hours	68°	6 hours	None.
	118 hours	72°	8 hours	None.
V*	23 hours	26°	Introduced	765
	28 hours	26°	7 hours	20
	48 hours	35°	24 hours	None.
	71 hours	57°	31 hours	None.
	96 hours	60°	48 hours	None.
			55 hours	None.
			72 hours	None.

*Grown in 5 per cent lactose broth.

TABLE XXII.—*Bact. lactis acidi* (*from sour milk*).

GROWN IN 1½ PER CENT LACTOSE BROTH.

Number of test.	Age of lactic culture.	Acidity of lactic culture.	Number of typhoid bacilli per cc. in filtrate.	
			Age of culture.	Count.
I	23 hours	18°	Introduced	7,645
	46 hours	37°	8 hours	3,890
			28 hours	214
			48 hours	12
			55 hours	2
			72 hours	2
			79 hours	None.
			144 hours	None.
			168 hours	None.
II	23 hours	33°	Introduced	3,898
	39 hours	42°	7 hours	None.
			24 hours	None.
			31 hours	None.
III	49.5 hours	42°	Introduced	2,813
			7 hours	528
			24 hours	None.
			31 hours	None.
			48 hours	None.
IV*	21.5 hours	39°	Introduced	10,496
			7 hours	7,823
			24 hours	2,385
			31 hours	1,814
			48 hours	82
			55 hours	13
			72 hours	1
			79 hours	None.
			96 hours	None.
			104 hours	None.
V*	23 hours	27°	Introduced	8,365
	28 hours	35°	12 hours	4,303
			25 hours	2,333
			48 hours	15,370
			55 hours	54,145
			72 hours	1,000,000
			79 hours	Uncountable.
			96 hours	Broth turbid.
VI*	48 hours	44°	Introduced	8,787
	70 hours	51°	7 hours	504
			24 hours	None.
			31 hours	1?
			48 hours	None.
			55 hours	None.
			72 hours	None.

*Grown in 5 per cent lactose broth.

TABLE XXIII.—*Bact. bulgaricum.*

GROWN IN 5 PER CENT LACTOSE BROTH.

Number of test.	Age of lactic culture.	Acidity of lactic culture.	Number of typhoid bacilli per cc. in filtrate.	
			Age of culture.	Count.
I	47.5 hours	23°	Introduced	53,580
	70.5 hours	26°	24 hours	880,200
	94 hours	28°	31 hours	Broth turbid, not plated.
II	23 hours	34°	Introduced	18,360
			12 hours	77,850
			24 hours	Broth turbid.
III	22 hours	25°	Introduced	6,288
	48 hours	26°	7 hours	700
	95.5 hours	53°	24 hours	152
			31 hours	85
			48 hours	1
			55 hours	None.

TABLE XXIV.—*Summary of Tables XX-XXIII.*

Lactic organisms.	No. of test.	Acidity of lactic culture.	Number of typhoid bacilli per cc.		
			Introduced.	Age of culture.	No. of *B. typhosus* present.
Bact. lactis acidi (from starter)	VII	24°	19,860	24 hours	Uncountable.
	VI	29°	1,422	288 hours	One.
	VIII	29°	5,626	99 hours	Uncountable.
Bact. acidi lactici, No. 2*	VI	28°	7,768	264 hours	Broth turbid.
	VII	30°	2,413	144 hours	None.
	VIII	34°	21,510	168 hours	(See Table XX).
Bact. lactis acidi, 53 B. 2	I	28°	11,106	24 hours	Broth turbid.
	II	56°	1,253	168 hours	Uncountable.
	V	60°	765	24 hours	None.
	III	68°	7,700	7 hours	None.
	IV	72°	381	2 hours	None.
Bact. lactis acidi (from sour milk)	V	35°	8,365	79 hours	Uncountable.
	I	37°	7,645	79 hours	None.
	IV	39°	10,496	79 hours	None.
	II	42°	3,898	7 hours	None.
	III	42°	2,813	24 hours	None.
	VI	51°	8,787	48 hours	None.
Bact. bulgaricum	I	28°	53,580	31 hours	Broth turbid.
	II	34°	18,360	24 hours	Broth turbid.
	III	53°	6,280	48 hours	One.

*These organisms produced their maximum acidity in each trial recorded.

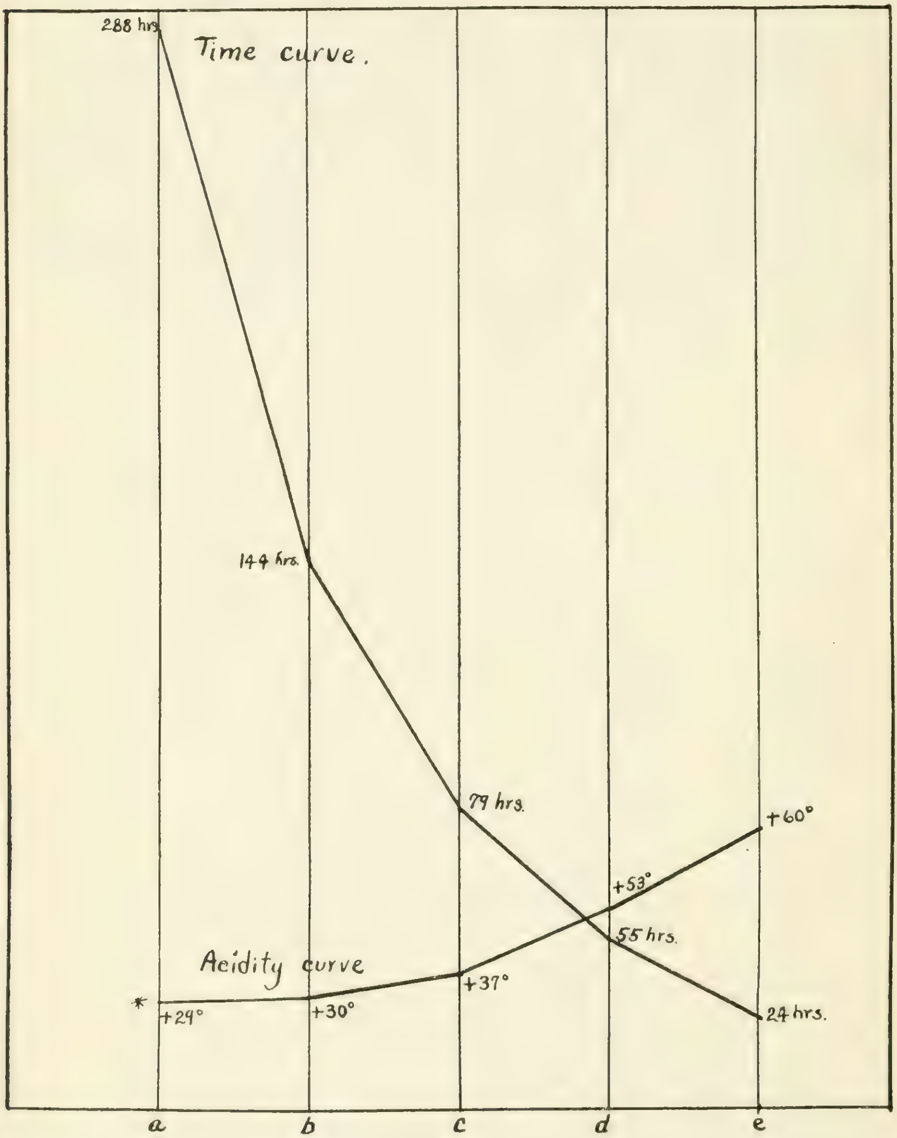
In the above summary, the following will be noted: The relative production of acid by the different lactic organisms *Bact. lactis acidi* (from starter), *Bact. acidi lactici*, No. 2 producing their maximum in each trial; the relative efficiency of the acid produced by each as a germicide. The germicidal power of each lactic is compared in Table XXV.

TABLE XXV.—*Germicidal Power of the five Lactic Organisms Compared.*

	Acidity.	Time.
Bact. lactis acidi (from starter) does not kill *B. typhosus*	At 28–29°	Within 288 hours.
Bact. acidi lactici, No. 2, killed *B. typhosus* in 1 out of 3 experiments	At 30°	Within 144 hours.
Bact. lactis acidi 53 B2 killed *B. typhosus*	At 60° At 68° At 72°	Within 24 hours. Within 7 hours. Within 2 hours.
Bact. bulgaricum killed *B. typhosu*	At 53°	Within 55 hours.
Bact. lactis acidi (from sour milk) killed *B. typhosus*	At 37° (in 2 expts.) At 42° At 42° At 51°	Within 79 hours. Within 7 hours. Within 24 hours. Within 24 hours.

The following curve illustrates the above table.

PRODUCTION OF ACID IN LACTOSE BROTH AND INHIBITIVE POWERS OF THE LACTIC ACID PRODUCED BY DIFFERENT ORGANISMS CONTRASTED.



CURVE 2.

Acidity curve shows minimum acidity producing total inhibition.
Time curve shows minimum hours recorded for inhibition to take place.
* = One typhoid colony found at the time recorded above.
a = *Bact. lactis acidi* (from starter).
b = *Bact. lactis acidi*, No. 2.
c = *Bact. lactis acidi*, (from sour milk).
d = *Bact. bulgaricum.*
e = *Bact. lactis acidi*, 53 B2.

Conclusion: *The time required for inhibition to take place is in inverse proportion to the minimum acidity producing inhibition.*

TABLE XXVI.—*Comparative Germicidal Power of Varying Amounts of Lactic Acid.*

Acidity of lactic culture.	Lactic organism.	No. of test.	Remarks.
28°	*Bact. lactis acidi* (from starter)	VII*	One typhoid colony developed on "1 cc." plate at the end of 8 days.
		X	Decreased in 7 hours; remained the same for 31 hours; increased.
29°	*Bact. acidi lactici*, No. 2	VI	Decreased in 7 hours; fluctuated for 216 hours, then increased.
		VII	Decreased in 7 hours; fluctuated for 72 hours; then *increased gradually.*
		VIII*	Typhoid bacilli killed within 144 hours.
30°	*Bact. lactis acidi*, 53 B2	I	Decreased in 7 hours; immediate and rapid *increase.*
30°	*Bact. bulgaricum*	I	*Increased* rapidly; no decrease.
34°	*Bact. lactis acidi* (from sour milk)	V	Decreased in 24 hours; rapid *increase.*
35°	*Bact. bulgaricum*	II	*Increased* rapidly; no decrease.
37°	*Bact. lactis acidi* (from sour milk)	I	Killed within 79 hours.
39°		III	Killed within 79 hours.
42°	*Bact. lactis acidi* (from sour milk)	II*	Killed within 7 hours.
		IV*	Killed within 24 hours (probably within 12 hours. See curve 2).
51°	*Bact. lactis acidi* (from sour milk)	VI	Killed within 24 hours (probably within 12 hours. See curve 2).
53°		III	Killed within 55 hours.
56°	*Bact. lactis acidi*, 53 B2	II*	Checks multiplication for 55-80 hours; then rapid *increase.*
60°	*Bact. lactis acidi*, 53 B2	V*	Killed within 24 hours.
68°	*Bact. lactis acidi*, 53 B2	III	Killed within 7 hours.
72°	*Bact. lactis acidi*, 53 B2	IV*	Killed within 2 hours.

*Less than 5000 typhoid bacteria introduced into each cc. of the filtrate.

OBSERVATIONS.

1. The typical lactic organism, *Bact. lactis acidi* (from sour milk) produces an acid which is inhibitive to *B. typhosus* in smaller quantities than the acid produced by any other of the above organisms. The minimum acidity recorded which destroys *B. typhosus* is 37°, or 0.3+ per cent lactic acid.

2. The acid produced by *Bact. lactis acidi* 53 B2, and *Bact. bulgaricum* reaches nearly twice 0.3 per cent before it is capable of destroying *B. typhosus.*

3. The lactic, *Bact. lactis acidi* (from starter) and the gas producer, *Bact. acidi lactici* No. 2 have a very uncertain inhibitive effect probably due to their failure to produce sufficient acid.

The acid produced by the most typical lactic organism is the most effective germicide for *B. typhosus* in lactose broth.

Experiment V.

Having reached such definite conclusions with regard to the germicidal power or inhibitive effect of the acid produced by these different lactic organisms in lactose broth, it becomes necessary to establish a relationship between lactose broth, and milk with reference to the relative amount of lactic acid which may be produced by these different lactic organisms in the different media. Whey was compared relatively with lactose broth and milk.

The following data, establishing the above, concludes this series of experiments:

TABLE XXVII.—*Relative Acidity Produced by Lactic Organisms in 5 per cent Lactose Broth, Whey and Ordinary Milk.*

Bact. bulgaricum.				*Bact. lactis acidi* (from sour milk).				*Bact. lactis acidi*, No. 4.			
Age of lactic culture.	Media.			Age of lactic culture.	Media.			Age of lactic culture.	Media.		
	Milk.	Broth.	Whey.		Milk.	Broth.	Whey.		Milk.	Broth.	Whey.
4 days	281°	*26°	82°	4 days	105°	55°	39°	4 days	68°	51°	30°
7 days	299°	115°	87°	7 days	114°	53°	37°	7 days	82°	55°	31°
10 days	309°	117°	88°	10 days	111°	53°	37°	10 days	87°	53°	31°
13 days	310°	117°	87°	13 days	113°	53°	35°	......	......	......	......
4 days	291°	*26°	83°	4 days	112°	52°	37°	4 days	70°	49°	31°
7 days	309°	107°	83°	7 days	113°	53°	38°	7 days	83°	52°	32°
10 days	321°	104°	84°	10 days	108°	54°	39°	10 days	87°	54°	32°
13 days	321°	107°	89°	13 days	101°	54°	39°	......	......	......	......
4 days	218°	76°	100°	4 days	112°	48°	41°	4 days	69°	52°	32°
7 days	314°	82°	103°	7 days	113°	49°	41°	7 days	86°	52°	34°
10 days	318°	88°	109°	10 days	112°	52°	41°	10 days	86°	***	34°
4 days	315°	50°	99°	4 days	114°	49°	38°	4 days	**83°	51°	34°
7 days	318°	56°	104°	7 days	119°	***	39°	7 days	91°	52°	35°
10 days	328°	60°	108°	10 days	119°	***	39°	10 days	97°	***	35°
4 days	299°	42°	94°	4 days	114°	48°	44°	4 days	**80°	49°	32°
7 days	310°	45°	99°	7 days	116°	50°	42°	7 days	89°	52°	35°
10 days	310°	62°	104°	10 days	115°	50°	44°	10 days	90°	53°	35°
4 days	303°	51°	99°	4 days	115°	48°	38°	4 days	**81°	50°	35°
7 days	312°	61°	101°	7 days	116°	51°	41°	7 days	94°	51°	33°
10 days	318°	102°	106°	10 days	117°	53°	43°	10 days	95°	52°	34°

**Bact. bulgaricum* was grown in old broth that was slightly concentrated (18°+). This may have caused the exceptionally high acidity.

The first four days the culture was kept at 21° which accounts for the low acidity at *. Afterwards these and the remaining cultures of this organism were kept at 37°C. The temperature seemed to have a marked effect on the production of acid in the whey cultures.

**Milk was used in these tests in which the lactose had been inverted in the process of sterilization. It has been observed that superheated milk (brownish in color), registers an amount of acid appreciably greater than that in unheated or in properly heated sterilized milk.

***Contaminated with molds. Cultures discarded.

The following table gives the average of Table XXVII with the corresponding percentages of acid produced in the different media.

From this table the amount of acid required for destroying *B. typhosus* in milk may be theoretically estimated.

TABLE XXVIII.

Name of organism.	Maximum average acidity.			Percentage of maximum acidity produced in		
	Milk.	Broth.	Whey.	Milk.	Broth.	Whey.
Bact. bulgaricum	314°	80°	101°	100	25.5	32
Bact. lactis acidi (from sour milk)	113°	52°	39°	100	46	34.5
Bact. lactis acidi, No. 4	89°	52°	33°	100	58	37

CONCLUSIONS.

The minimum acidity produced by *Bact. lactis acidi* (from sour milk) which will destroy *B. typhosus* is +37° in lactose broth. This corresponds to 80° acid in milk and 28° acid in whey.

The minimum inhibitive acidity produced by *Bact. bulgaricum* is +53° in lactose broth. This corresponds to +208° acid in milk and to 66° acid in whey.

The above amounts of acid in milk corresponding to the acidity produced in whey and lactose broth by the same organism are theoretically the minimum acidities at which the typhoid bacteria will be killed.

However, in raw milk, the medium of natural infection, many factors enter which are never constant, e. g., the character of the initial microbial flora, the flora gained by the necessary exposure to sources of contamination, and the temperature conditions under which the milk is kept after being strained.

If certain species of microörganisms are present in milk, they may, either by growing in association with the lactic bacteria, or by some of their own metabolic products cause a more rapid destruction of the typhoid organisms than the lactic bacteria are capable of causing alone. Or, on the contrary, certain species of bacteria may predominate which will check the production of acid by the lactic bacteria, some even living in symbiotic relationship with *B. typhosus*.

It is very probable that some one of these conditions will occur in the greater number of infected milk samples since milk infected with typhoid bacteria must have been subjected to sources of contamination from which a varied flora would be acquired.

Thus, while this series of experiments brings out some very interesting facts in regard to the influence of fermentation lactic acid upon typhoid bacilli, the many factors entering under natural conditions prevent any definite conclusions being made when these natural conditions exist.

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MICHIGAN

STATE AGRICULTURAL SOCIETY.

MICHIGAN STATE AGRICULTURAL SOCIETY.

To the President and members of the Executive Committee of the Michigan State Agricultural Society:

Gentlemen.—I submit herewith my report of the Sixty-second Annual State Fair and recommendations for your consideration for the next State Fair.

The first and foremost requisite of a successful State Fair is its exhibits. The quality, of course, is first to be considered and the quantity and arrangement make the exhibit attractive to the spectator. The Agricultural Department should be first in order for your consideration.

This exhibit at our last State Fair was a credit to the state and tastefully arranged for the benefit of the patrons of the Fair, but I think some better arrangements can be made in the manner of selecting and securing the several exhibits from the different Bureaus.

I would set aside space along the walls of the Agricultural Building in as near equal amounts as possible and have the counties make their exhibits through their respective Bureaus, for the reason that each Bureau is better able to arrange and collect its exhibits, as they have someone in charge who is familiar with the work, and this is not usually the case with respect to the county exhibits.

Another reason for this plan is that the county exhibits would pass through a sort of elimination process by coming under the Bureau. We would then have a well balanced exhibit of real merit, as the poor and commonplace part of the exhibit would be weeded out.

I would then have a competitive exhibit between the four Bureaus and make a suitable award to the winning exhibit or Bureau. By so doing we would stimulate interest between the Bureaus, thus giving us a better quality of exhibits and no county would lose its identity because the competing Bureau could not afford to cripple its exhibit on account of favoritism, because they would be anxious to win the award, hence we would get the best possible exhibits from the individual as well as the county and suffer no bad results because of this elimination as the whole arrangement and selection would be up to the respective Bureaus.

I would then reserve the center section of the Agricultural Building for individual exhibits and truck farmers of Wayne and nearby counties.

In my opinion we are fortunate indeed to possess these Development Bureaus, and we should make use of them in this way, as better results can be obtained through organization of this kind than soliciting individual exhibits. This fact is clearly shown by the strenuous efforts now being made by sister states to organize and promote these Bureaus throughout their territory.

DAIRY DEPARTMENT.

The new dairy barn erected this year affords the farmers a practical opportunity of seeing how dairying should be carried on to obtain the best results.

It was demonstrated by practical illustrations and lectures that cleanliness was one of the first requisites for successful dairying. Improved methods were taught the farmer and the exhibit of dairy machinery in operation certainly was advantageous to the many interested spectators.

However, this exhibit was not as complete as we can make it, and as this department mirrors one of the leading industries in the state, better facilities must be provided to enable us to make a showing worthy of the great dairy intrests in Michigan.

As a suggestion, suppose we plant an acre or so of corn in the spring and invite one of the numerous manufacturers of ensilage machinery from the im-

plement department to come over and fill our silos with this corn, thereby giving an interesting exhibit and providing the Society with some good feed for the winter.

I believe it would also be a good plan to invite some of the instructors from the Michigan Agricultural College to come down and lecture on the relative values of feed and the cost of producing same in different localities, as scientific feeding is necessary to produce the best results.

Particular attention must be paid to the practical side of this subject, because this appeals to the farmer, as it shows him how to obtain more dollars and cents from his investment.

Of course, we cannot expect to have a creditable exhibit in this department until the dairy building is completed. With this end in view I would favor hiring Mr. Buck of Coldwater to go ahead with this building early in the spring, using the lumber and material on hand that was necessary to erect the nine foot wall around the cement floor of the new dairy building, as this material can be used to good advantage, thereby saving us $350 yearly which is the amount required for the tent roof.

In connection with this department, a rule should be passed compelling all the exhibitors of dairy machinery to show in this building or not exhibit at the Fair. I think when these exhibitors have an opportunity of seeing this structure completed they will be better satisfied to show there instead of in the implement department, thus bringing us in more revenue besides assisting in making a creditable dairy show. A charge of fifteen cents per square foot should be made for space in the dairy building.

LIVE STOCK DEPARTMENT.

This live stock exhibit of 1910, really put the Michigan State Fair on the map as we had one of the best live stock departments in the west. More exhibits of better quality were shown with the single exception of the Minnesota State Fair. Various reasons have been advanced to account for this great showing when comparing it to the 1911 exhibits in this department.

In my opinion, two causes worked the change, viz.: first, a nine day fair and second, the cutting of premiums in our open classes to permit us to give twenty per cent additional to Michigan winners. A nine day fair under our rules compels an exhibitor to have his stock on the ground at nine o'clock on the opening day of the Fair, and specifies that he must remain until the end of the ninth day or forfeit all premiums. It is common knowledge that many county fairs offer fairly good premiums and the exhibitors can make two of these fairs while he is attending ours and win more money. Besides, these short jumps often assist in getting the exhibitors' stock to another state fair following us in better shape than if he were to make the distance in one shipment.

It is a mistake to cut our premiums in order to add twenty per cent to the winnings of Michigan breeders, because Michigan show cattle, horses, sheep and swine can compete anywhere and make a good showing (if the best in Michigan is shown). If not, we do not need the poor ones simply to fill the stalls and draw premiums. Again, there is no State Fair in the Union discriminating in the open classes (some states provide a class open to state exhibitors only, but this does not effect the open classes).

I have carefully gone over our records and find that the twenty per cent rule did not bring out any more good Michigan live stock, as the following tabulation shows:

1910.	MICHIGAN PREMIUM WINNERS.	1911.
14	Horses	12
8	Swine	9
10	Sheep	9
21	Cattle	17

In other words, the twenty per cent clause did not serve its purpose, viz.: bringing out more good Michigan live stock than heretofore.

HORSE DEPARTMENT.

In my opinion, the Horse Department needs little comment for the reason that it seems to be in first class shape, and, excepting for an unfortunate combination of circumstances would have been better than last year. The Crouch Farm of Lafayette, Indiana, (who are a whole show in themselves) would have been here with nineteen cars of horses, except for an unforeseen shipping difficulty, and Finch Brothers, another last years' exhibitor, backed out at the last moment because of some trouble in the past with one of our judges, but we had a very creditable showing as it was in the heavy draft classes.

The night horse show was the best ever seen in Michigan, and is getting better every year. It is a real credit to our State Fair and premiums should be increased, thereby making this exhibit more attractive than ever.

I would make this one suggestion, however, that all judges in the Live Stock Department be changed next year. No irregularities have occurred to my knowledge, but I think a change as suggested would be for the better.

IMPLEMENT DEPARTMENT.

The Implement Department was the best ever seen at any State Fair, both in number of exhibits and arrangement of same, and great credit has come to the Michigan State Fair as a result of the magnitude and diversity of the exhibits made in this department.

EDUCATIONAL DEPARTMENT.

The Educational Department was first class and had a greater number of exhibits tastefully arranged than any other exhibit of its kind previous to the 1911 State Fair. I would suggest that we abolish the rule restricting the amount of premiums won by any school to $100.00. In my mind, this is unfair to the up-to-date schools with thousands of pupils who collectively make a much larger display than the small country schools with nine or ten pupils, because it is as fair to assume that a large breeder of live stock should be curtailed in the amount of premiums he can win.

NEEDLEWORK DEPARTMENT.

The Needlework Department would be better off in some other location, as it seems to me to be out of place in the Michigan Building, especially so because the majority of people are not as much interested in this department as in others. In other words, the prominent position of this exhibit is out of proportion to the importance of the exhibit.

SPEED DEPARTMENT.

You already have an exhaustive report from the Secretary of Races covering the financial side of this department. However, I have made a tabulation of the expense of free attractions in front of the grand stand and amount of purses paid for horse races, also, the amount of revenue derived from this department, and this tabulation may assist you in determining the amount of purses we are to offer in the future.

Statement showing receipts from grand stand and cost of attractions since 1909.

	Day and Night Grandstand Receipts.	Expenses and Race Purses.	Race Revenue, Entry Fees, Etc.	Free Attractions.
1908	$18,069 50	$11,805 64	$6,805 50	$17,569 97
1909	13,584 75	6,396 23	4,740 50	15,009 50
1910	11,934 50	29,050 00	24,104 00	13,164 42
1911	17,095 00	35,754 00	37,700 00	12,732 69

VEHICLE DEPARTMENT.

There were more than double the number of vehicles displayed on the main thoroughfare and on the avenue leading to the Automobile Building than ever before, and the representatives of the different lines complained bitterly of the dust and other bad features connected with their location.

I also wish to call your attention to the valuable space occupied by this exhibit, and to my way of thinking, the nuisance of large tents of varying colors housing these vehicles. For example: The Flint Buggy Company occupied a space 125 by 200 feet and the next exhibit was 40 by 60 feet. The former exhibit was enclosed in a round top tent and the latter in a square tent, and such was the case on both sides of the drive. As a result, we had an unsightly arrangement.

I believe it would be good policy to provide for the erection of a vehicle building on the same plot of ground occupied by the Implement Building and place the vehicle exhibit there, because the interests of the vehicle and farm implement manufacturers are identical, and it would not do to separate the two departments to the extent of forcing the vehicle exhibitors to show on the upper floor of the Automobile Building, providing we are able to do so. I would arrange to have this building similar to the Implement Building, except to use brick piers instead of the steel posts along the outside wall, which would give the building a more substantial effect, besides lessening the cost of construction.

At the time this report was written, I had no opportunity of getting estimates on this building, but same will be on hand during the meeting, and if the scheme meets with your approval I believe, with the assistance of the superintendent of last year's vehicle display, we could secure enough permanent exhibits in this department to bring us fifteen or twenty per cent on our investment.

That this suggestion merits your consideration, I have only to recall your attention to the returns on our investment in the Automobile Building which exceeds twenty-five per cent, besides bringing us more revenue through the gates.

TRANSPORTATION DEPARTMENT.

This phase of State Fair work has been evolved to such an extent during the last two years that it has become one of the big departments of the Fair. Heretofore scarcely any attention was paid towards securing additional railroad tracks and the grading of same, and as a result of obtaining these facilities recently the thousands of shipments containing exhibits to the State Fair can be reached by the truck men at any point on the Grand Trunk siding, thus affording an easy means and quicker transfer of the exhibits to and from the cars.

Bids were asked and received from local trucking and transfer companies who have the facilities to take care of the loading and unloading of the heavy machinery and sufficient teams and trucks on the ground to quickly take care of the transferring of exhibits to and from all departments. The Association did not make one cent from this privilege, but imposed conditions upon the people they asked to make bids on the teaming and trucking to the extent of compelling them to publish a schedule of prices and requiring them to provide facilities for handling the entire proposition and all details connected with it.

The Reading Truck Company was finally selected to do the work and they performed their duties satisfactorily to the management of the Fair, as well as to the satisfaction of the numerous exhibitors.

However, there is one matter in connection with this department that must be remedied before the next Fair. We must keep out the cheap one-horse expressman and nearby farmers from coming in on the grounds and transferring the lighter exhibits at cut prices with no regard to taking care of the situation. These people are undesirable because we cannot depend on them to do any stated amount of work, as we have no supervision over them and they are not accountable to us for their work. Neither is it fair to the Truck Company, because we demand that they keep eight or nine teams in readiness to take care of all the work, and part of the time they are forced to remain idle because of the actions of the undesirable parties referred to above. If something is not done with reference to this matter we will have trouble in the future in taking care of the trucking because no company will contract to do the work under the present conditions, and as a result our exhibitors will become dissatisfied.

The superintendent of this department handled all tickets and badges in

connection with his other duties in a satisfactory manner. There was no confusion, and everyone entitled to a ticket or pass obtained same without any trouble. I think it wise to handle this work in the same manner next year, as the Finance Committee is sometimes engaged elsewhere and cannot attend to the details of handling the tickets and badges. Furthermore, concise reports containing all information relative to tickets and badges were made daily and handed to the proper officials.

I wish to call your attention to another matter in connection with this department. We have no freight sheds and all L. C. L. shipments must lay in the cars or remain on the platform between the side tracks until such time as they can be moved, and the Grand Trunk should be compelled to build suitable sheds for housing these shipments, as they have a monopoly on all freight shipments to and from the State Fair Grounds.

To follow the same line of reasoning, we compel the D. U. R. to build shelter stations, establishing up-to-date exits and walks for the convenience of our passenger traffic, but the Grand Trunk Railway is given sufficient space for their tracks and possess the same rights and privileges in the freight traffic that the D. U. R. does with the passenger traffic and they should be compelled to provide for the convenience of their patrons in the above manner.

In my opinion, a resolution should be passed after consultation with Railroad Commissioner Dickinson, making it mandatory on the part of the Grand Trunk Railway to erect a suitable building about 40 by 80 feet on their siding for the purpose of housing all L. C. L. shipments during the Fair.

GATE RECEIPTS.

We will first take up the matter of outside gate receipts and I herewith submit a tabulation showing the amount of gate receipts for the last four years, beginning with 1908 and ending with 1911:

Total gate receipts as per annual report 1908...........	$59,348 26
Total gate receipts as per annual report 1909...........	53,820 83
Total gate receipts as per annual report 1910...........	60,004 95
Total gate receipts as per annual report 1911...........	60,989 50

These figures represent a total of all gate admissions from all sources and include the revenue derived from advance sale of tickets during 1908 and 1909. This comparison is made for the purpose of showing that more actual money was collected from a smaller attendance during 1910 and 1911 because it is fair to assume that more people will attend the State Fair during good weather, as was the case in 1908 and 1909, than when we had from two to three days rain and a street car strike to contend with this year.

This proves that the pay-as-you-enter system is superior to the old ticket system as far as the outside gates are concerned.

In my opinion, the same conditions exist relative to equipping the grand stand entrances with the Bright Turnstile, as I can see no reason why the patrons of the grand stand are entitled to leave and return the same day without paying an additional fifty cents any more than they should expect to go down town after paying their fifty cents admission at the outside gate and expect to be readmitted to the grounds again because they have previously paid one admission on that day.

We provide free toilet service in the enclosure around the grandstand, beside first class facilities for eating and drinking inside the stand. Confections and cigars are sold and peddled all through the grand stand, so no excuse or complaint can be offered by the patrons for leaving the grand stand and expecting to return free. If this plan is carried out we will eliminate all chance of forged tickets, switching badges and the usual irregularities that accompany the ticket system; also the expense of printing tickets except the few reserved and box tickets which can be sold in the usual way without interfering with the cash turnstile system because the reserve tickets are issued simply to designate a certain box or seat after the purchaser has paid his general admission to the grand stand.

CONCESSIONS AND PRIVILEGES.

A rule was passed by the Business Committee compelling all concessionaires to purchase their daily admittance to the grounds; also raising the price of corner concessions twenty-five per cent. This is a good rule except in many cases it is hard to follow, for example: The Detroit Creamery, New England Pie Company, Barlum's Wholesale Meat Company and Vernor's Ginger Ale concessions hire boys to peddle their wares on a commission of fifty per cent and the average wages of these boys will not exceed sixty cents per day. Therefore, it is impossible to force these boys to pay fifty cents to get into the grounds.

One advantage this rule has brought about is that we actually know the number of admissions each concession requires, and the number of tickets used by each concessionaire has been written on his 1911 contract. Under these circumstances, the Fair Association could afford to give free tickets in similar amounts next year, and if the concessionaire demands more tickets I could show him his 1911 contract and explain to him that this number of tickets was all he needed for the same concession during 1911 when he was compelled to pay for them, and of course, refuse to give him any more. As a matter of fact, this class of tickets netted the Fair but $1,000 this year.

I think it was noticeable that the concessions of this year were of a better class, and less fakirs were on the ground than in previous years, and with the idea of eliminating all undesirable concessions, I think it would be policy to limit all concessions to $100, thereby barring the cheap jewelery, knife racks and other undesirable concessions. We would suffer but little financial loss and gain much in prestige by making a rule of this kind, and the Michigan State Fair can afford to take this step, as was proven this year, because, minus the bar privileges and a large number of the above concessions, the State Fair Association cleared over $24,000. Besides we should look more to what is best for the State Fair in the future rather than how much money we derive from these undesirable concessions. This also applies to the bar privilege, because it is more obnoxious to a large number of our patrons than the cheap concessions referred to above.

I wish to further emphasize the statement because the mere fact that the state does not make a donation for paying premiums or making improvements to the grounds, as in other states, and up to the present time has failed to take any steps towards taking over the State Fair, is no excuse for selling the bar privilege, because we must keep our skirts clear. Some of you may say we will be unable to pay the interest on the bonds or meet the current expenses until next Fair unless we let the bar privilege. My answer to this is that we got along under the most trying weather and other adverse conditions during the past two years without the bar, and as a result, the standards of our Fair have been greatly increased. Furthermore, in my estimation, it is hardly logical to advertise a great educational treat and a short course in agriculture to our patrons and then bring our boys and girls to the Fair and exhibit a saloon in full operation on the grounds.

It has also been stated that the Toronto Fair, which is the largest on the Continent, operates a bar. As a matter of fact, no intoxicating liquors are sold, but a beverage called "Star Beer" is sold which tests under one per cent. Besides it is commonly known that no State Fair in the Union is selling intoxicants of any kind on its grounds. The only reason that can be advanced for selling this privilege is that we need the money and cannot get along without it and pay our expenses and premiums. However, if a correct depreciation charge and proper distribution of earnings had been made previous to 1910, the net profits of last year's Fair would compare favorably with those of any year during which liquor was sold on the State Fair Grounds. It is also well to mention the fact that better weather conditions prevailed previous to 1910 and 1911, as no bad weather was encountered during the Fairs of 1906, 1907, 1908 and 1909.

APPRAISAL OF LAND AND BUILDINGS OWNED BY THE SOCIETY.

A practice has been followed in making out the annual report of charging all work on buildings, water and sewerage systems, electric light plants and other real estate, to the Permanent Improvement Account. This practice has resulted in an inflated valuation of this property. For example, I beg to call your atten-

tion to the amount charged to the electric light plant, which according to the last annual report amounted to $23,011.88. As a matter of fact it is doubtful if the plant is worth half this amount. Under the circumstances it was imperative that an appraisal of this property be made, and with this idea in view, we engaged the Hannan Real Estate firm, Mr. Wooley, President of the Detroit Real Estate Board and Mr. Milby, Architect, to make an appraisal of the buildings and land owned by the Society.

A total charge of $411,468.45 stood on the books representing the building and permanent improvements to the land. The depreciation charge against these buildings has cut this total to $366,159.38. This would have been a dangerous practice if followed and would have resulted in misrepresentation of the real value of our holdings. Fortunately for us, the land acquired by donation from the citizens of Detroit and the purchases made by the Society were carried on our books at $103,357.12 and the appraisal showed this land to be worth $208,912.50. The entire depreciation charge on the buildings and other permanent improvements amounts to $73,381.62 which is subtracted from the building account of $411,468.45 and shows the actual value of our property.

In the future we will open a separate account with each building, and a maintenance and repair fund will be established to be separate and distinct from the permanent improvement account, thus preventing an inflated valuation of the real estate and fixtures in the future. I wish to comment on the depreciation charge made on some of the buildings, namely, The Michigan Building and Speed Barns, which was made necessary because they were set upon wood underpinnings. I believe it is advisable to substitute cement or stone underpinnings for all wood foundations, thereby reducing the depreciable cost on these structures.

SUGGESTIONS FOR THE FAIR OF 1912.

Inasmuch as we have purchased the Pay Closets, I think they should be open to the public, and if advisable we can equip, say six or eight of the toilets in each building with a nickle-in-the-slot lock, thereby affording privacy to such of our patrons as are willing to pay for this privilege.

Another matter that deserves your attention is the establishment of a permanent, first class dining hall where the patrons of the Fair can obtain good clean food in a respectable place at a reasonable price.

This arrangement can be brought about by making a contract with some first-class caterer who possesses the facility for operating a serve-self lunch and dining room, and for this purpose I would lease one-half of the space under the grand stand and arrange it so as to give access to all visitors outside as well as those in the stand.

If this suggestion is followed, we will be filling a long felt want, besides adding a valuable asset to the Fair. I think you all agree that the majority of pleasure seekers at a State Fair or at any other public amusement place, desire good clean food properly served, as it certainly adds to their pleasure, and we, as providers, should do all we can for the entertainment and convenience of our guests.

I would also establish a short course in Agriculture, Dairying and Animal Industry for representative young farmer boys chosen from the different counties throughout the State.

The State Fair would receive thousands of columns of free advertising in the country press as a result. Besides every farmer in Michigan would learn of this plan through the pupils attending the country schools where the examination for applicants would be held, thereby bringing his attention to the State Fair and interest would be aroused among the farmers and their annual attendance would be assured.

Just estimate the number of boosters the State Fair would secure among the farmers provided this school was continued for five years, as no boy would be allowed to succeed himself. Hence, we would have one thousand young men praising the efforts of every member of this board who assists in promoting the school. In addition to the boys' individual advertising, relatives and acquaintances of each would take an active interest in all matters pertaining to our State Fair.

Advertising such as this cannot be approached in effectiveness, because it really interests the people we desire to reach, and the money I am asking you to appropriate for this cause can be deducted from our advertising fund.

What we really need now for the betterment of everyone is more farmers, farming scientifically and the State Fair of Michigan can do more towards promoting this movement than any other agent, not excepting our Agricultural College at Lansing, and what is more, it is our duty, because it is one of the fundamental objects of an up-to-date State Fair.

I respectfully suggest the following plan of starting the great movement of "back to the farm" throughout the great State of Michigan.

Organization of School: The Michigan State Fair Association will give 100 boys an opportunity to study the best methods in agricultural and animal industry at the State Fair in Detroit, September 16 to 21st, under the direction of experts from the Michigan Agricultural College and other well known authorities on stock raising, diseases of live stock, etc.

Competitive examinations will be held in each district school under the supervision of the County Superintendent, and all boys between the ages of 14 and 19 years are eligible to take the examination, providing the applicant intends to following agricultural pursuits. The five boys obtaining the highest credits in examinations will meet a committee composed of the Local Master of the State Grange, County Superintendent of Schools and the Chairman of the County Board, who will pass on the candidate's fitness to take the course, examinations to count 50 per cent and the knowledge of agriculture and general fitness the remaining 50 per cent. The candidate best fitted in the minds of the committee is to be given a free trip to the Fair and all his expenses paid while in Detroit.

A certificate will then be issued in duplicate to the winner by the County Superintendent, and upon receipt of the same the boy will retain one copy and forward the other to the Secretary of the State Fair, Detroit, Michigan.

All candidates are expected to arrive at the State Fair grounds not later than Monday noon, September 16, and report to the State Fair office immediately. Boys should bring towels, soap, comb, brush, collars, needle and thread and also a pair of blue overalls, colored shirt and blue handkerchief which will be worn while on parade. Valuable watches and jewelry must be left at home. Profanity or dissipation of any kind will not be permitted. Rules and regulations similar to those of any well organized camp will be laid down and any violation on the part of the candidates means expulsion.

Tents and cots will be provided by the State Fair in a permanent camping ground established on the plot of ground opposite the Main Building.

Five hours work each day will be required from the boys in cleaning up the grounds and other light work. The balance of the day will be taken up with lectures and visiting the different exhibits in squads of ten or twelve under the direction of Y. M. C. A. assistants. The boys will also be given opportunity of assisting in judging in the show rings, agricultural and horticultural departments.

Lectures each day will be given in one or more of the following subjects, by a recognized authority.

Animal Industry,
Dairy Products,
Agriculture,
Horticulture,
Road making,
Diseases of farm stock.

In addition to these lectures, we will have a talk from the Governor of the State and one or two members of the Executive Committee of the Michigan State Fair.

In order that this program may be successfully carried out, a superintendent must be appointed in charge of the work who will give his time and attention to the numerous details in connection with the program, and the selection of this superintendent, should in my mind, be made by the President and Business Committee. I think we can expect co-operation of the State Grange, Gleaners and other worthy organizations in developing this movement.

There follows a detailed list of premiums and awards.

Respectfully submitted,
J. E. HANNON,
Manager.

PREMIUMS AND AWARDS.

CATTLE.

Class.	Breed.	No. of Entries.	Herds.	Offered.	Awarded.
1	Short Horns (open to all)....	90	30	$614 00	$557 00
	Special paid by American Short Horn Association.				
	Steers	15		148 00	140 00
	Short Horns (open to Mich.)..	42	15	230 00	172 00
	Polled Durham	67	20	671 00	431 00
	Special paid by Polled Durham Breeders' Association.				
	Hereford	50	19	671 00	444 00
	Special paid by American Hereford Cattle Association.				
	Aberdeen Angus	65	26	671 00	471 00
	Special paid by Aberdeen Angus Breeders' Association....	31			
	Galloway	13	4	671 00	211 00
	Jersey	72	17	655 00	589 00
	Special paid by American Jersey Cattle Club.............	5			
	Guernsey	45	12	655 00	481 00
	Holstein-Friesian	54	17	655 00	405 00
	Special paid by Holstein-Friesian Association.				
	Ayrshire	66	20	648 00	553 00
	Red Polled	90	32	614 00	581 00
	Brown Swiss	47	15	607 00	435 00
	Dairy Cows	10	..	100 00	100 00
	Fat Steers	21	6	115 00	115 00
	Herdmen's Special			30 00	30 00
	20% paid on Michigan bred cattle........................				252 00
		783	233	$7,753 00	$5,967 00
	Paid by American Short Horn Association.....................				169 00
					$5,798 00

HORSES.

Class.	Breed.	No. of Entries.	Offered.	Awarded.
14	Standard Bred	46	$451 00	$368 00
	No class 15.			
16	Hackney	63	436 00	383 00
17	French and German Coach....	3	436 00	36 00
18	American Carriage	60	443 00	365 00
19	Percheron	10	492 00	148 00
	Special paid by Percheron Asso.			
20	Clydesdale	19	465 00	244 00
21	English Shire	3	472 00	32 00
22	Belgian	11	459 00	159 00
23	Heavy draft mares and Geldings	36	311 00	244 00
	No class 24.			
25	Shetland Ponies (breeding stock)	25	172 00	141 00
26	Jacks and mules............	0	142 00	
27	Roadsters	59	300 00	300 00
28	Roadster class...............	69	1,100 00	1,100 00
29	Saddle class	72	720 00	720 00
30	Shetland Ponies	31	225 00	200 00
		507	$6,624 00	$4,420 00
	20% paid on Mich. Bred Horses............................			138 60
				$4,558 60

SHEEP.

Class.	Breed.	No. of Entries.	Herds.	Offered.	Awarded.
31	American Merinos	76	13	$210 00	$194 00
32	Delaine Merinos	69	10	210 00	181 00
	No class 33.				
34	Rambouillet	76	10	210 00	210 00
35	Lincoln	83	14	210 00	202 00
36	Leiscester	30	6	210 00	187 00
37	Cotswold	69	9	210 00	202 00
38	Shropshire	132	17	210 00	202 00
	Special paid by Shropshire Association.				
	Oxford Down	3	3		
	Special by Oxford Down Association.				
	Hampshire Down	69	7	216 00	159 00
	Special by Hampshire Down Association	61	7	210 00	183 00
	Southdown	69	14	210 00	185 00
	Horned Dorset	37	7	210 00	152 00
	Fat Sheep	49	11	90 00	60 00
	20% paid on Mich. bred sheep				124 00
		823	111	$2,406 00	$3241 00

SWINE.

Class.	Breed.	No. of Entries.	Herds.	Offered.	Awarded.
44	Berkshire	64	15	$347 00	$288 00
	Special by American Berkshire Association	6			
	Special by Hibbard and Baldwin.				
	Special by C. L. S. Bartlett				
	Poland China	25	4	352 00	8 00
	No class 46.				
	Hampshire	37	12	352 00	217 00
	No class 48.				
	Victoria and small Yorkshire	38	12	352 00	311 00
	Chester White	48	11	352 00	308 00
	Large Yorkshire	39	8	352 00	259 00
	Duroc-Jersey	71	16	352 00	263 00
	Special by Duroc-Jersey Association.				
	Tamworth	51	12	352 00	299 00
Fat hogs		0	0	44 00	
20% paid on Mich. bred swine					154 00
		373	90	$2,855 00	$2,107 00

POULTRY.

Class.		No. of Entries.	Pens.
55	AMERICAN:		
	Barred Plymouth Rock	32	3
	White Plymouth Rock	15	3
	Buff Plymouth Rock	23	3
	Partridge Plymouth Rock	11	0
	Silver Penciled Rock	12	0
	Columbian Rock	4	0
	Golden Wyandottes	10	0
	Silver Wyandottes	9	1
	Buff Wyandottes	14	1

AMERICAN:	No. of Entries.	Pens.
Black Wyandottes	9	1
White Wyandottes	12	2
Silver Penciled Wyandottes	8	1
Partridge Wyandottes	18	1
Columbian Wyandottes	10	1
R. C. Rhode Island Red	28	2
S. C. Rhode Island Red	21	2
Buckeyes	5	2
Dominiques	11	0
White Javas	8	2
Mottled Javas	3	0
ASIATIC.		
Brahmas light	14	1
Brahmas dark	9	3
Cochin buff	7	1
Cochin partridge	9	0
Cochin black	5	0
Cochin White	6	1
Langsham black	15	3
Langsham white	12	2
ENGLISH.		
Dorkins, colored	6	0
Dorkins, silver gray	10	0
Dorkins, white	1	0
Orpingtons, R. C. buff	7	1
Orphingtons, S. C. buff	24	2
Orpingtons, R. C. black	0	1
Orpingtons, S. C. black	13	1
Orpingtons, R. C. white	13	1
Orpingtons, S. C. white	44	5
Orpingtons R. C., spangled	8	0
Orpingtons, S. C. diamond		
Jubilee	1	1
Red Caps	12	1
Lakenvelders	0	1
FRENCH.		
Houdans	13	2
Favorelles	0	0
GAME.		
B. B. Red		0
Brown Red	4	0
Duckwing Silver	2	0
Duckwing Golden	0	0
Red Pyle	6	0
White	2	1
Black	3	0
Birchen	0	0
Cornish Indian	11	1
White Indian	9	1
Black Brown Red M. G.	0	0
MEDITERRANEAN.		
Spanish Black	7	0
Minorcas Black R. C.	10	0
Minorcas Black S. C.	24	3
Minorcas White R. C.	6	1
Minorcas White S. C.	9	1
Andalusians	14	1
Leghorns R. C. White	29	4

	No. of Entries.	Pens.
MEDITERRANEAN.		
Leghorns S. C. White	27	3
Leghorns R. C. Black	4	1
Leghorns S. C. Black	7	2
Leghorns R. C. Brown	15	4
Leghorns S. C. Brown	15	3
Leghorns R. C. Buff	8	1
Leghorns S. C. Buff	14	2
Leghorns Silver		
Ducklings	7	2
HAMBURG.		
Hamburg C. Penciled	11	1
Hamburg S. Penciled	10	2
Hamburg C. Spangled	4	0
Hamburg S. Spangled	7	2
Hamburg Black	9	1
Hamburg White	5	2
POLISH.		
White Crested B. Polish	11	2
White Polish	2	0
Golden Polish	14	1
Silver Polish	12	2
Buff Laced Polish	4	0
Gold Bearded Polish	4	0
White Bearded Polish	4	0
Silver Bearded Polish	8	0
GAME BANTAMS.		
Black Brown Red	9	1
Brown Red	8	0
Duckwing Silver	4	1
Duckwing Golden	2	0
Red Pyle	4	0
White	6	0
Black	1	0
Birchen	2	0
Cornish Indian	0	0
White Indian	2	0
Black Brown Red M. G.	0	0
ORNAMENTAL BANTAMS.		
Golden Seabright	11	1
Silver Seabright	2	1
R. C. White	10	2
R. C. Black	6	1
White Booted	2	0
White Cochin	2	0
Buff Cochin	10	1
Partridge Cochin	8	1
Black Cochin	20	1
Light Braham	7	0
Dark Braham	5	0
Black Tailed Japanese	11	0
White Japanese	5	0
Black Japanese	1	0
White Crested Polish	2	0
Barred Plymouth Rock	2	1
R. C. Buff	0	0
White Leghorn	2	0
MISCELLANEOUS.		
Sumamtra Black	10	1
Mottled Anconas	16	0
Silkies	12	0

TURKEY.	No. of Entries.	Pens.
Bronze	8	0
White	7	0
Buff	0	1
Black	7	1
Slate	6	1
Narragansett	10	1
DUCK.		
Pekin	16	1
Roun	14	1
Aylesbury	12	0
Indian Runner	10	0
White Call	13	0
Gray Call	14	0
Black India	10	0
Cayuga	11	0
Crested White	9	0
Muscovy Colored	11	0
Muscovy White	9	0
GOOSE.		
Toulouse	13	0
Embden	10	0
African	15	0
China White	16	0
China Black	13	0
Buff	6	0
ORNAMENTAL FOWL.		
Pea Fowl	1	0
White Guinea	3	0
Pearl Guinea	4	0
English Pheasant	2	0
Any other variety	3	0

PIGEONS AND HARES.

PIGEONS.		
Archangels	0	0
Barbs	0	0
Carriers	0	0
Dragoons	0	0
Fantails	2	0
Homers	5	0
Jacobins	0	0
Magpies	1	0
Nims	0	0
Owls	0	0
Oriental Frills	0	0
Turbites	1	0
Pouters	7	0
Runts	0	0
Swallows	4	0
Tumblers Short face	0	0
Tumblers	2	0
Tumblers Muffled	3	0
Tumblers Parlor	0	0
Tipplers	0	0
Trumpeters	1	0
Ancients	0	0
Bell Neck Tumblers	0	0

PIGEONS.	No. of Entries.	Pens.
Crescents	0	0
Fire Backs	0	0
Florentines	0	0
German Beards	0	0
Helmets	0	0
Monks	1	0
Priests	1	0
Swifts	0	0
Starlings	2	0
HARES.		
Belgians	37	2
Flemish Giants	14	2
Dutch Rabbits	10	1
Angora or silk hares	6	0
Himalayan	13	1
Cavies	4	1
Non-enumerated	7	1
	1,403	124

Total amount awarded $2,087 50
Total amount offered 2,500 00

AGRICULTURE.

Class.		No. of Entries.	Offered.	Awarded.
56	Grain and Seed	232	$597 00	$545 00
	Corn	130	308 00	259 00
57	Roots and Vegetables	450	395 50	343 00
	Coll. Vegetables	32	357 00	268 00
58	County Exhibit	6	600 00	240 00
	Non-Enumerated	2		
		852	$2,257 50	$1,660 00

DAIRY.

Class.		No. of Entries.	Offered.	Awarded.
59	Creamery Butter	11	$100 00	$85 14
	Dairy Butter	14	50 00	49 94
	Cheese	8	174 00	56 20
60	Domestic Manufacturers	157	75 00	75 00
	Non-Enumerated	2		
			$399 00	$269 28

APIARY.

Class.		No. of Entries.	Offered.	Awarded.
61	Bees and their products	69	$265 50	$263 50
	No classes 62, 63, 64.			

NEEDLEWORK.

Class.		No. of Entries.	Offered.	Awarded.
65	Professional	647	$401 75	$325 50
	Amateur	879	435 25	340 00
	Non-enumerated	150		55 50
		1,676	$837 00	$721 00

HORTICULTURE.

Class.		No. of Entries.	Offered.	Awarded.
67	County Exhibit	8	$640 00	$400 00
68	Collections and Displays	216	1,272 00	1,015 00
69	Single Plates			
	Apples	596	200 25	166 50
	Pears	170	90 00	62 75

		No. of Entries.	Offered.	Awarded.
	Peaches	203	$112 50	$103 00
	Plums	133	101 25	82 50
	Grapes	93	65 25	55 50
	Quinces	15	9 00	7 50
	Cranberries	0	6 75	
70	Dried, Canned, Pickled, Preserved Fruits, etc.	340	273 25	268 75
71	Plants in Pots Professional	26	379 00	172 00
72	Plants in beds and boxes Professional.	21	319 00	104 00
73	Cut Flowers Professional	27	265 50	109 50
74	Plants in Pots, Amateurs	0	29 75	
75	Cut Flowers, Amateurs	62	171 00	95 00
	Non-Enumerated	15		4 00
		1,925	$3,934 50	$2,646 00

EDUCATION.

76	Country Normal	142	$228 00	$204 00
77	High School	103	189 00	134 00
78	Grammar	140	241 00	201 00
79	Intermediate	408	207 00	191 00
80	Primary	276	131 00	131 00
81	Manual Training	235	285 00	208 00
82	Village Schools	0	148 00	
83	District Schools	178	222 00	177 00
	Non-enumerated	22		44 00
		1,504	$1,651 00	$1,290 00

Amount awarded two school	10 00
	$1,300 00
Amounts not paid to schools receiving over $100.00	232 00
	$1,068 00
Total amount to Northeastern Development as per premium list	360 00
Cost of ribbons, cups, badges and medals	802 37

Total number of entries, 10,665.
Total prizes offered, $31,482.50.
Total amount awarded, $24,583.25.

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